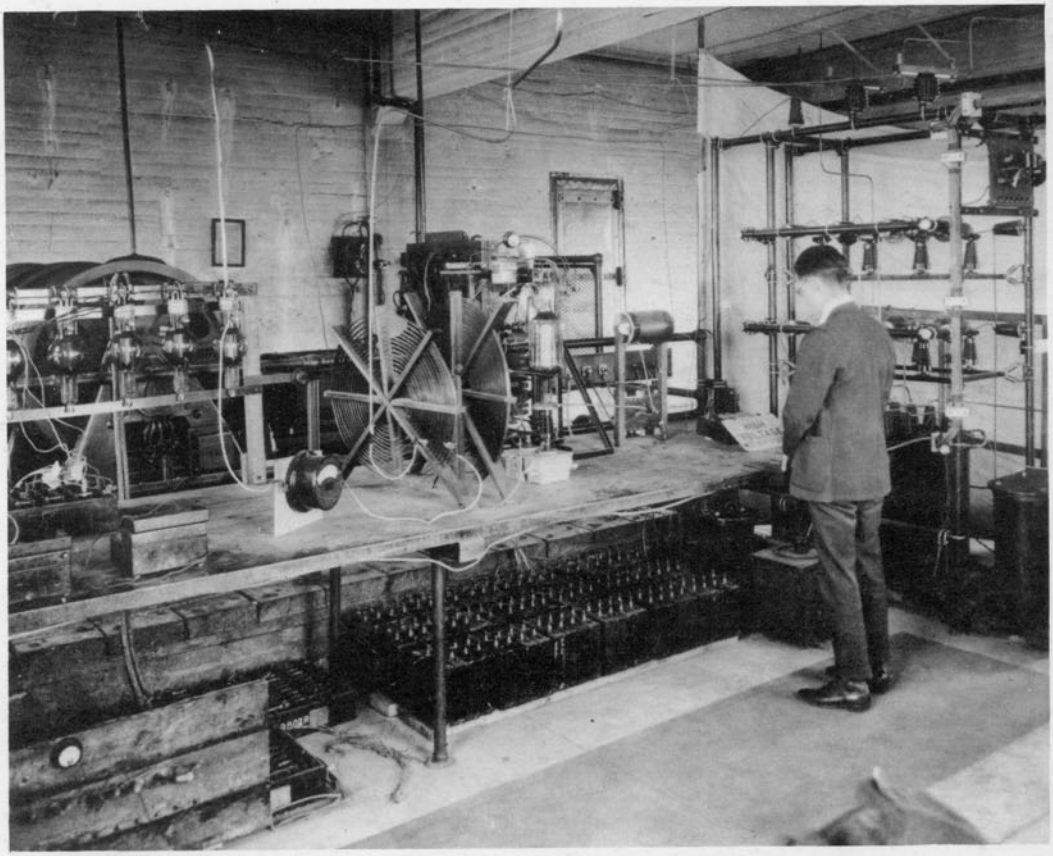
AWA

# THE AWA REVIEW



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# THE AWA
# REVIEW

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# THE AWA REVIEW

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THE COVER

The "WGY Power House," in Building 40 of General Electric's facility in Schenectady, New York. This section of a broadcast transmitter of the early '20s is truly a developmental item, from the lab-bench physical layout to the operator-safety system (a sign reading HIGH VOLTAGE - DO NOT TOUCH). For some of the lessons learned in the early years of broadcasting, see the article "A Glimpse at Old-Time Transmitter Development" in this issue.

*Photo by courtesy of the Hall of History Foundation, Schenectady.*

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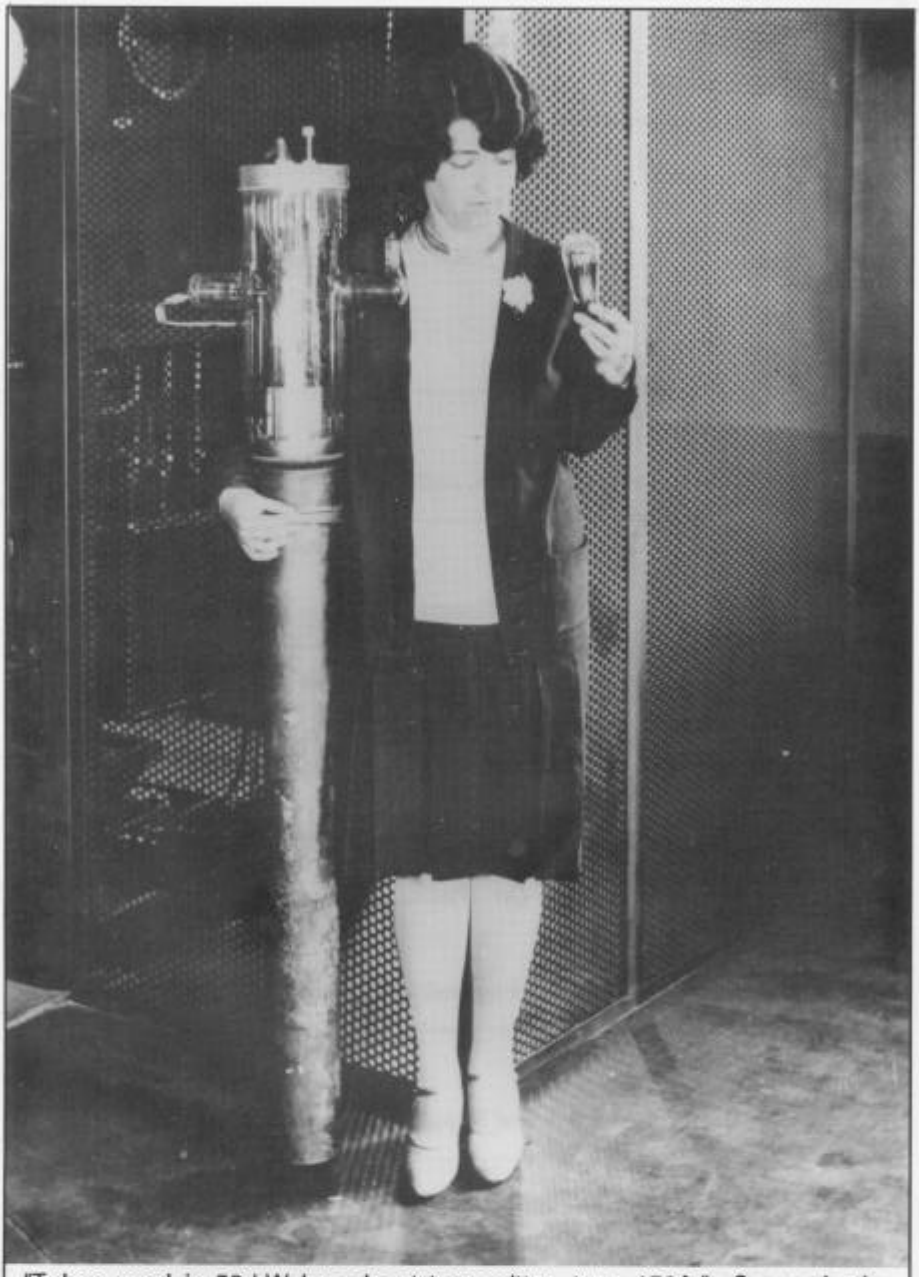


"Tubes used in 50-kW broadcast transmitter, type 152A." So reads the caption on this GE publicity photo from 1929, contrasting the mighty UV-862 with the humble UX-210. Judging from the dark scale on the copper anode, the big tube has some operating hours on it. Comparing the photo with a GE UV-862 photo from 1945, the internal construction is quite a bit different, and the seal-off tube at upper right points down, not up as shown. For the quirks of the 862 as a linear amplifier, see p. 149.

*Photo: Hall of History Foundation*

# FOREWORD

This 1993 issue of the AWA Review offers insight into a spectrum of historical topics.

In "Unusual Military Morse Keys," Louis Meulstee presents a group of British and European wireless and radio keys with the equipment that used them. This includes some intriguing "agents' sets" as well as military radios from the West and the Eastern Bloc.

Years ago, tube expert Gerry Tyne gave a talk to an AWA audience on some particularly early and scarce tubes. His "Rare Tubes: How to Recognize Them, and Why They Are Rare" has been brought from the archives to a new audience, with the aid of photos by Jerry Vanicek.

Today's radio historian knows of Reginald Fessenden vaguely, as a prolific wireless inventor. However, we are generally unaware of the variety and volume of his publications. "A New Bibliography of Reginald A. Fessenden," assembled by David Kracuter, reveals how extensive the inventor's writings were.

The Federal Telephone and Telegraph Company of Buffalo is widely known as a source of collectible radios, from the Junior crystal set and Model 61 tube receiver to the "Ortho-sonic" consoles of 1929. But two-thirds of Federal's lifespan was in the telecommunications industry, struggling with the local Bell company for survival. "'Federal' as a Telephone Company" by Ludwell Sibley shows the forgotten side of this firm.

The *other* Federal was the California group that built arc transmitters and provided radiogram service. Its direct descendant is alive today. "The KFS-Federal-Mackay Story: From CW Arc to Silicon Valley" by Hank Olson and Bill Orr traces the origins of today's coastal station KFS from the Federal Telegraph Company.

One of the greater surviving collections of early vacuum tubes is the one assembled by a figure little known today. In "Joseph T. Fetsch: Vacuum-Tube Engineer and Collector," Jerry Vanicek covers the career of this individual and gives photo coverage of his collection.

Many of the prime radios of WW I vintage came from "NESCO." In 1961, AWA printed Ted Duvall's "A History of the National Electrical Supply Co." NESCO can be traced back to 1885 or so, and forward to several present-day electronics firms. We've updated this history and expanded it for today's reader.

In Review 6, Fred Chesson published his handy directory to Signal Corps radios of the 1915-43 BC-SCR-RC era. Now, in "Navy Electronics Directory," we have a comparable guide to Navy electronic equipment of the same vintage.

Many AWA members have experience "debugging" newly built transmitters for efficiency and stability, but we have no idea how hard this work was in the early days. "A Glimpse at Old-Time Transmitter Development" is a 1930 report by GE engineer Walter Nelson on his difficulties - and success - in taming a big (200-kW) experimental broadcast transmitter.

*The Editor*

# UNUSUAL MILITARY MORSE KEYS

**Louis Meulstee, PA0PCR**
Schiedam, Holland

## SUMMARY

Described in this paper is a fascinating selection of unusual and "concealed" Morse keys used for military and semi-military signalling, with emphasis on British and Continental armed forces. Much effort has been taken, not just to depict a key by itself, but to describe briefly the type and function of the signalling instrument with which the key was used. It is apparent that a standardized key of a particular pattern was often used in a number of different sets or instruments.

In World Wars I and II, on both sides of the line, very similar signalling systems were devised, but the general layout of the instrument and shape of the Morse key differed considerably.

A classification of design and variations of the British standard "KEY W.T. 8 AMP" is given, including a number of applications in which this key was used.

Changes in the Warsaw Pact countries' policies have lifted the barriers on information on military communication equipment. The USSR and its then-satellite (Warsaw Pact) countries designed military Morse keys; their applications are included in this selection of keys.

## INTRODUCTION

Most Morse keys are easy to recognize; some models, however, are not so obvious and are often concealed as part of an instrument.

In this article a variety of unusual Morse keys are presented. Not only is a description of the Morse key given, but also background information on the type, function, and operational use of the instrument in which the key was mounted.

The Morse keys in this paper are classified by the function of the instrument or its epoch, as shown below, rather than by the model or pattern of the key. The exception is the KEY W.T. 8 AMP, which receives special attention.

- Clandestine ("suitcase") Radio Communication
- Beacons and Homing Systems
- Remote-Control Units
- Visual Signalling
- World War I Radio
- Wireline Equipment
- Miscellaneous and Warsaw Pact Radio
- Training Keys
- The KEY W.T. 8 AMP

Morse keys used with suitcase radio equipment for clandestine (agents') operations were usually of the miniature type. However, they were often mounted in the set to reduce the number of external accessories. Additionally, a number of conventionally styled military Morse keys are presented, which were either mounted in a special instrument or had a unusual feature and function. Signalling keys on Air-Sea Rescue transmitters and such homing systems as Eureka-Rebecca, having only a secondary role of use for identification purposes like

Fig. 1. British "Type 3 Mk 2 "

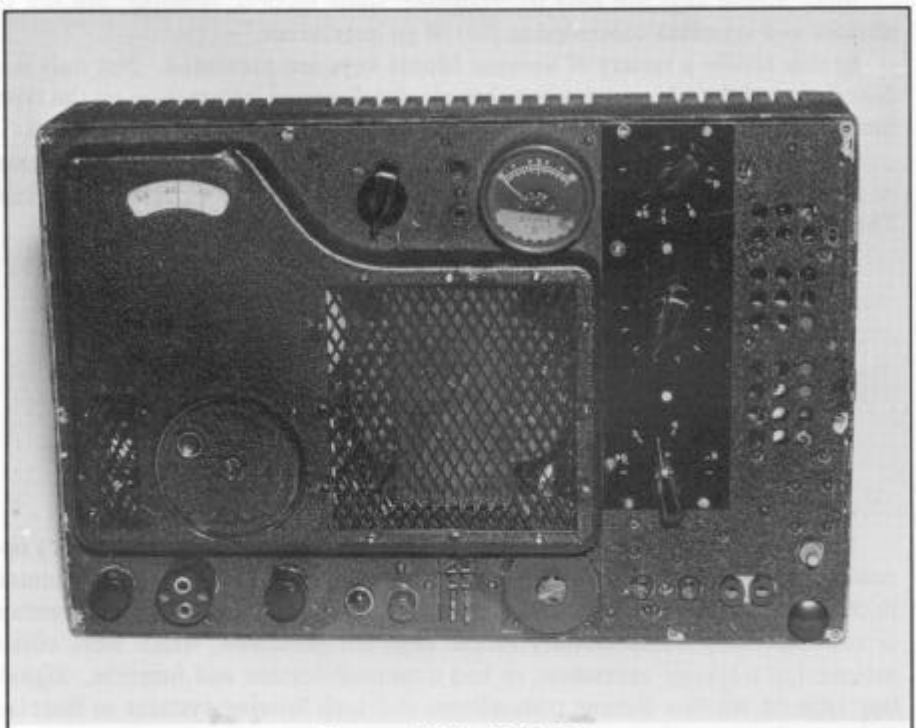


Fig. 2. British Mark 121

sending a few pre-arranged letters in Morse, were considered within the scope of this treatise.

Following the unification of East and West Germany, a large portion of the armed-forces radio equipment of the former German Democratic Republic has been scrapped. A small part of it has found its way to the surplus market in Western Europe, including interesting Morse keys designed in the USSR and its satellites. Only a few years back, these keys were virtually impossible to obtain. Photographs of examples and their applications, which only recently came to the attention to the author, are included.

Collecting Morse keys mentioned in this article not only would take much space, but would be a difficult task, as most of the equipment is extremely rare. However, an individual key in the reader's possession may have been mounted previously in an instrument described in this paper. Of the vast number of signal instruments and key varieties, only a representative selection was made for inclusion.

It is interesting to see how such design features as the folding key, making its first appearance in World War I, were still used well after WW II.

Included is the history of the British KEY W.T. 8 AMP, giving an account of the development and basic variations of this well known standard Morse key, including its use in a variety of "Key and Plug Assemblies." Other applications of this key are found throughout this paper.

In some cases where both photographs and drawings were available, preference was given to drawings, as they often provide a better view of the key. Unless stated otherwise, all equipment is British.

## CLANDESTINE OPERATIONS

Although now virtually obsolete and replaced by satellite communication, short-wave radios, sometimes hidden in a suitcase, provided the primary means of communication between agents or isolated special forces (e. g., the Special Air Service of the British) and their bases. Except for special radiotelephone (R/T) systems such as the British S-Phone and U. S. Joan-Eleanor*), communication was in only Morse, allowing the use of simple, low-powered transmitters.

The system of pre-coded messages on tape or other means, speeding-up the transmission of a message to reduce the risk of interception, was used in only a few cases during World War II. Generally use was made of more or less conventional Morse keys. On the whole, the one thing the keys had in common was miniaturization.

**Fig. 1.** "Type 3 Mk 2" ("B2") was one of the most successful British suitcase sets. Developed early in WW II, it can hardly be considered as miniature. The set comprised four units: transmitter (top), receiver (bottom), power supply (right) and accessories case (only lid shown). In use, the miniature Morse key is mounted on top of the accessories lid. This model key was typical for many types of British suitcase sets of that era.

---

* Both operating on UHF full-duplex, usually from an aircraft at high altitude to the agent on the ground. This allowed rapid communication, usually recorded on a wire recorder in the aircraft.

Fig. 3.
British
"A Mk III "

Fig. 4.
British
"Mk 51/1 "

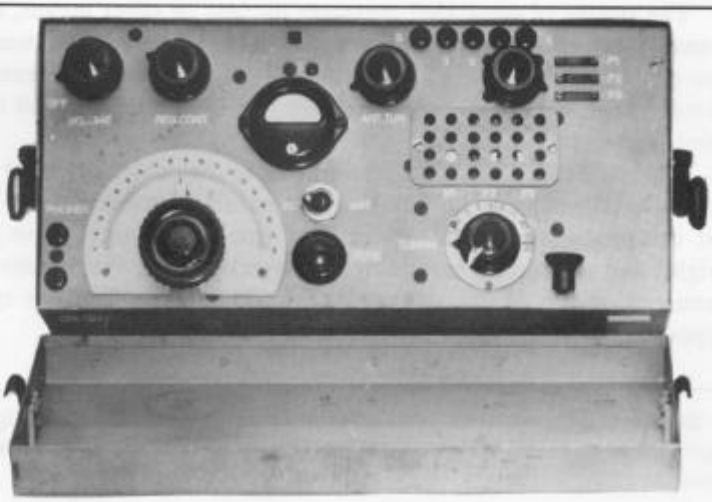


Fig. 5.
German
SE 99/10

**Fig. 2.** British Mark 121 (model B), developed in the 1950s. The set is powered from its internal mains power unit or, alternatively, by a hand generator or six-volt vibrator power pack. The crystal-controlled transmitter, operating from 4.3 to 9 MHz, gives 10-13 watts RF from a 2E26 power amplifier. The receiver is a three-tube superheterodyne. The internal Morse key is custom-made, its contacts mounted in a plastic block and suitable only for mounting underneath the front panel. The key does not appear very strong; the main lever of the one in the author's set was badly bent on receipt. A socket on the front panel provides for connecting an external Morse key or high-speed Morse transmitter.

**Fig. 3.** British "A Mk III" was a clandestine radio, primarily for communication over medium distances. The Morse key, similar to that used with the "B2," is mounted in a bakelite box with an additional protective cover over the lever. In operation the key is clipped onto a steel plate, providing a stable fixture. The case is marked S250/I.B.

**Fig. 4.** British WW II agents' transmitter "Mk 51/1." This remarkable miniature transmitter was so small that it could be carried in the agent's pocket. It was self-contained and powered by 200-250 volt AC mains. It operated between 3 and 10.5 MHz in two bands and produced about 1-2 watt of RF from a crystal-controlled oscillator/power amplifier. The internal sub-miniature Morse key is visible to the left of the tuning control, above the crystal socket.

**Fig. 5.** German "Kleinst-Agentenfunkgerät SE 99/10" of WW II. This transmitter-receiver was used not only with German agents, but also with the SD (*Sicherheitsdienst*, or internal security). Note the Morse key mounted on the bottom right front.

**Fig. 6.** In the British Mark 122, having three frequency ranges but otherwise similar to the Mark 121 of Fig. 2, the fragile Morse key was replaced by a more robust type, fixed on top of the front panel. The key is of straightforward construction, made of pressed steel.

**Fig. 7.** Close-up view of the Morse key used in the German agents' set type SE 99/10 of Fig. 5.

**Fig. 8.** Radio Station Mk 217 had an internal key similar to that of the Mk 121. The set is divided into four units for concealment and ease of transport. Receiver (left), transmitter (center), mains power supply unit (right) and vibrator power pack (extreme right, not connected).

**Fig. 9.** British Radio Stations Mk 123 and A3 were developed after the war for agents and special forces. Both sets had an internal Morse key of the same pattern: a square button, mounted at the side of the transmitter-receiver. It had a fixed gap and pressure. While looking awkward to manipulate, this type of Morse key operates easily and smoothly.

Mk 123 dated from the late 1950s. It was compactly built, having three basic sub-chasses. The set operated from 2.5 to 20 MHz. The transmitter was crystal-controlled, delivering 15 to 25 watts of RF, depending on frequency. When no mains source was available, it was powered by a hand-generator or 12-volt power pack. Provision was made for connecting an external Morse key or mechanical keyer. Though tubes were used throughout, the transmitter side-tone circuit used a transistor.

**Fig. 10.** British postwar agents'/special forces Mk 128. This was a portable station housed in a wooden case and carried in a canvas pack. It was powered by

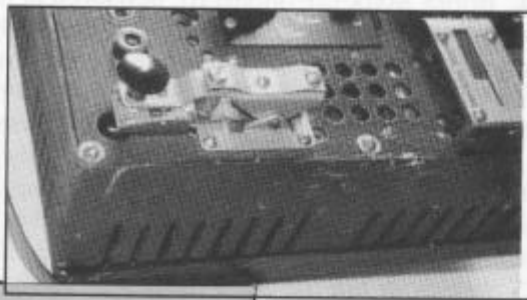


Fig. 6. Key of Mark 122

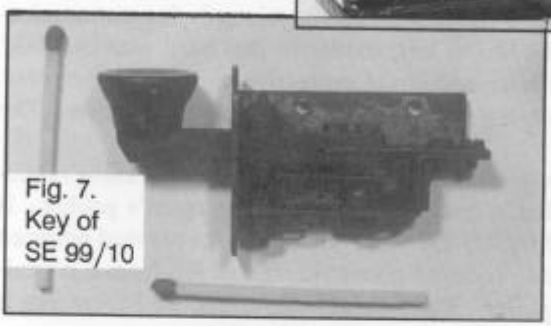


Fig. 7. Key of SE 99/10

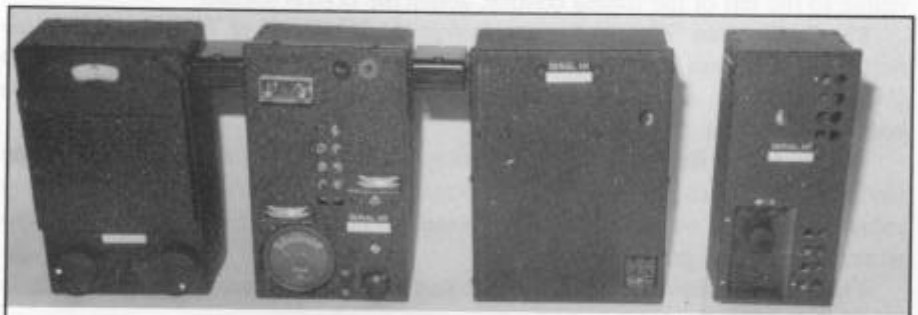


Fig. 8. British Radio Station Mark 217

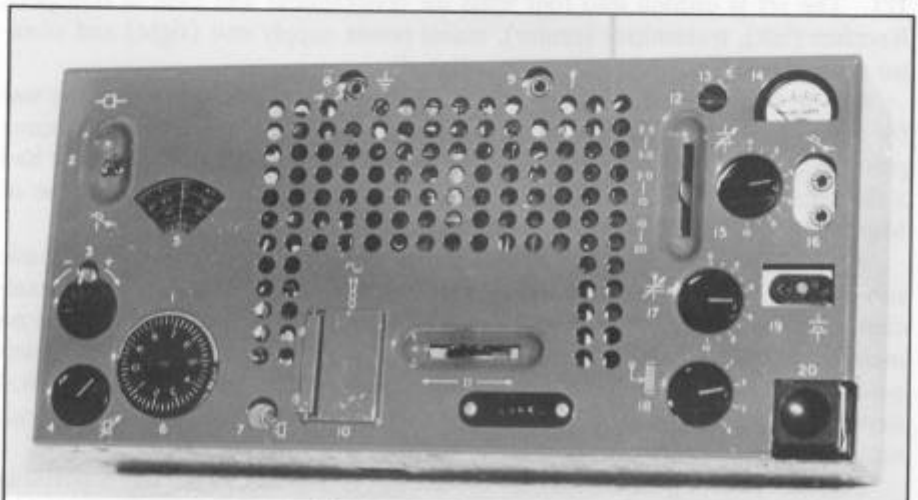


Fig. 9. British Mark 123

dry batteries. Mk 128A and Mk 128B were other versions, having a different case. The station was used in the 1960s. Top: receiver unit, center: transmitter unit, bottom: battery compartment. Other compartments held accessories to make the station self-contained. The set covered the range of 2-8 MHz in two bands. The crystal-controlled transmitter delivered approximately 1 watt RF, CW only. The Morse key was mounted on the inside of the front panel, which formed an operating table when the station was set up.

**Fig. 11.** Mk 128B Morse key, mounted on a plastic base. Removing the bakelite cover reveals a key of very simple construction, apparently without a space contact. The key examined by the author had no sign of the maker's identification.

**Fig. 12.** British Radio Station A3, developed in the early 1950s, operated from 3.5 to 17 MHz. It comprised three units. Shown in the photograph are the mains power unit and transmitter only.

**Fig. 13.** Transmitter unit RT-6 of US clandestine radio station RS-6 shares several interesting constructional features with the German SE 109/3 (Fig. 14). The RS-6 was a miniature postwar transmitter-receiver comprising five units including separate transmitter, receiver and power unit. The transmitter has an internal key which can be folded away into the case when not in use. A separate Morse key or automatic tape keyer can be connected to the key jack on the front panel. The frequency range of the set was 3-16.5 MHz in two bands, delivering 6-10 watts RF.

**Fig. 14.** The German SE 109/3 agents' transceiver (1944-45) was the last model developed by the former Abwehr. The set was built into a pressed "biscuit tin" case with easily removable top and bottom cover plates. It operated on dry batteries. The transmitter was crystal-controlled; the receiver had three type DF11 metal tubes. The Morse key, seen here ready for operational use, has a removable (plug-in) lever.

**Fig. 15.** British M.I.9 transmitter concealed in an imitation-leather covered cigarette tin. The transmitter is crystal-controlled. It operates from AC mains, having a tiny internal transformer. The Morse key of this ultra-miniature transmitter slides back into the case when not in use.

**Fig. 16.** USSR transceiver type GRANIT. The 1960s set operates on short wave between 3.5 and 4 MHz (one would suspect amateur use . . . ), and is powered by dry batteries. It has a plug-in lever-type Morse key.

**Fig. 17.** M.I.9 transmitter disguised as a cigarette tin. Apparently the transmitter was powered by internal dry batteries. Considering the aerial length (30") and the size/windings of the transmitter coil, its estimated working frequency is in the low end of the VHF band (50-70 MHz), consequently having a very limited range. The Morse signals were modulated by a small buzzer unit. The armature of the on/off switch, here seen on the side of the case (in operational use, on top) acts in "on" position as a Morse key.

## BEACONS AND HOMING SYSTEMS

Air-Sea Rescue (ASR) transmitters operating on the 500-kHz distress frequency were developed in World War II for ditched air-crews. Most of the sets were self-contained and powered by an internal hand generator. They had a re-

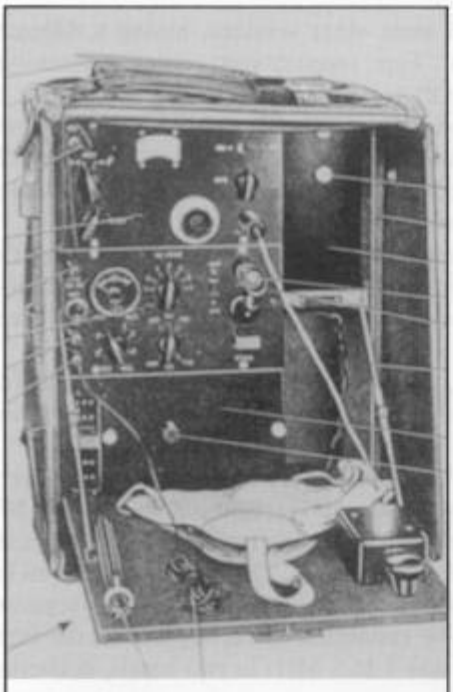


Fig. 10. British Mark 128

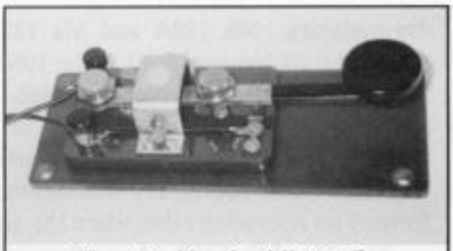


Fig. 11. Key for Mk 128B

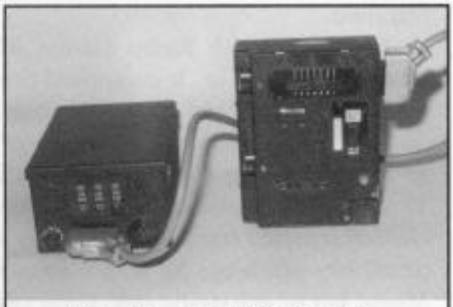


Fig. 12. Radio Station A3.

Fig. 14. German SE 109/3

Fig. 13. US RT-6

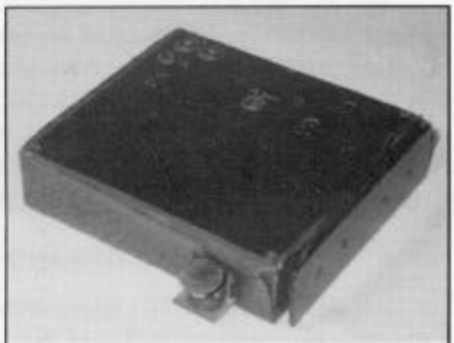


Fig. 15. British M. I. 9 transmitter

markably ergonomic shape, fitting between the operator's legs during operation. Transmission of pre-coded "SOS," followed by a long dash, was automatically sent in Morse by turning the generator handle on the ASR transmitter. However, when a rescue aircraft was in sight, a normal Morse message could be transmitted by using the key mounted on the front of the set.

**Figs. 18, 19, 20** (top to bottom). Air-Sea Rescue transmitters: German NG2, British Type 33, and USA SCR-578. All operated on the 500-kHz distress frequency. The Allied transmitters were copies of the NS2.

The Rebecca-Eureka system was developed by the British early in WW II, primarily as a homing device for dropping agents and supplies into occupied Europe. Soon the possibility of use by paratroops was realized and the equipment enhanced for this purpose. It was used in virtually all airborne operations in the second half of the war. The system consisted basically of the "Rebecca," an airborne VHF interrogator set, and a "Eureka" ground transponder.

The Rebecca-Eureka system used pre-arranged code words. Two-letter codes were usually transmitted to the aircraft in Morse prior to a drop in order to verify the authenticity of the ground station. The key is mounted on the front panel under a rubber weatherproof cover. Keying the Eureka involved changing the pulse-width of its transmitter, which was read by the airborne operator on his Rebecca screen. The Rebecca was keyed simply by switching the interrogator-transmitter.

**Fig. 21.** US-made Eureka responder beacon RT-37/PPN-2 (1945). A headset jack, providing reception of Morse signals sent by the airborne operator, is located to the right of the key (a push-button switch for coding).

**Fig. 22.** British Mk II Eureka transponder beacon TR3174 (1943). On the left is the six-volt power pack, at right the transmitter-receiver unit. Pulse-width keying was accomplished by the "K" button.

## REMOTE CONTROL UNITS

It is not always convenient or even possible to place a radio exactly at the position where communication is required, owing to the need of concealment and to avoid screening. Most British field radios were designed for remote-control working, enabling a second operator situated some distance away from the set to transmit and receive in Morse and voice. Usually two remote-control units were used with a radio, one directly connected to the set (the nearby or "local" control) and the other at the distant point (the "remote" unit), both units connected by twisted field wire. Of the large number of remote-control units known, only a selection is given. Most of them differed only in general layout and added features.

**Fig. 23.** Wireless Remote Control Unit "A." It provides the facility to operate Wireless Set No. 1 or No. 11 from a distance. The unit is enclosed in a metal case and includes a standard KEY W.T. 8 AMP No. 2 (design 1B, described later), which is fixed-mounted on the chassis. An additional feature is the connection to a buzzer-call telephone switchboard for connection of a telephone set to the radio.

**Fig. 24.** Wireless Set No. 21. This British set was a low-power transmitter-receiver for short-range R/T and CW communication in infantry brigades and

Fig. 16. USSR GRANIT transceiver

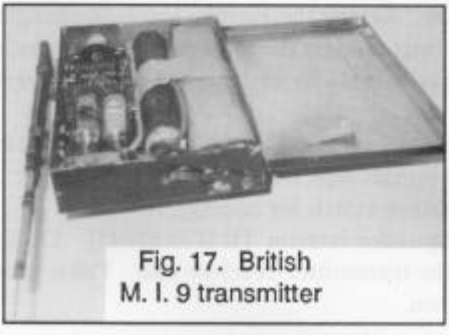


Fig. 17. British M. I. 9 transmitter

Fig. 21. US RT-37/PPN-2 Eureka transponder

Fig. 18. German NG2 distress transmitter

Fig. 19. British Type 33 distress transmitter

Fig. 20. US SCR-578 distress transmitter

Royal Artillery regiments, operating at 4.2-7.5 and 19-32 MHz (1940 onwards). It carried a detachable panel with essential controls including a Morse key. When in use, the control unit was removed from the case and mounted on the operator's table, normally connecting to the set by a short cable. When required to work at a distance, it was connected to the set through a special five-wire extension lead 120 meters in length. The operator at the control unit could transmit voice and Morse, hear received signals, switch between receive and transmit, and make slight adjustments to the receiver tuning. No local operator was necessary when operating from a remote position. The Morse key in this unit is a standard KEY W.T. 8 AMP No. 2 Mk II (design 2B), with an extension rod on the key knob.

**Fig. 25.** Remote-control unit "K," and remote-control unit "K," Mk 2, British stock code ZA 51445 or NATO Stock No. Z1/5820-99-949-1174. Note the different sockets on the two units and the absence of a call button on the Mk 2 unit.

Remote Control Unit "K" (also called "K" box) was part of the postwar British Army radio control harness type "B," used from the mid-1950s onwards. This unit was used for remotely controlling vehicle-mounted HF radio sets in the Larkspur range, e. g., Station(s) Radio C11, C12 and C13, when Morse keying functions are required. It connected to the (local) radio by means of paired field cable, for which the terminals can just be seen on the right side of the key cover.

Two screw adjusters on the key enabled the user to vary the spring tension and the length of the gap. As with many of the British field keys, two canvas straps were provided for securing on the operator's knee when in use. Two five-way sockets were fitted on the unit for the attachment of headsets and microphones. A call button sounded a buzzer at the local side, enabling the user to call the local operator and speak to him via the intercom.

An alternative "KV" version is known, produced for fixed installation (local keying) in vehicles. It has two round six-point sockets (one on each side, for connecting the unit to the cable harness) and no straps or call button.

A later manufactured "K" Mk 2 remote-control unit was very similar to the "KV" unit. It could be operated adjacent to the installation or at the remote point. Two carriers were provided into which the K unit was fitted for operation: the "Carrier, fixed remote control, K, Mk 2" could be screwed to the operator's table, while the "Carrier, free remote control, K, Mk 2") had two straps for securing it to the operator's knee. It is similar to the key made in South Africa, depicted in "Foreign and Military Telegraph Keys," AWA Review Vol. 3, p. 116, Fig. 50.

**Fig. 26.** "Remote Control Unit L NO. 2" (ZA 29007) was used with Wireless Sets No. 62 (Fig. 105) and C12 from the late 1940s to the 1960s. The unit is very similar in shape to the Key and Plug Assemblies Nos. 8, 9 and 19, having a KEY W.T. 8 AMP NO. 2. However, the key in the "L" Control Unit is the miniature type as used with clandestine sets B2 and A Mk III (Figs. 1 and 3). Two pairs of headphones can be connected on the sockets on the right side. The left side of the unit has a four-point socket for a microphone and a pair of slotted terminals (one just visible in the picture) for connecting the control line to the "Set Control Unit L No. 1."

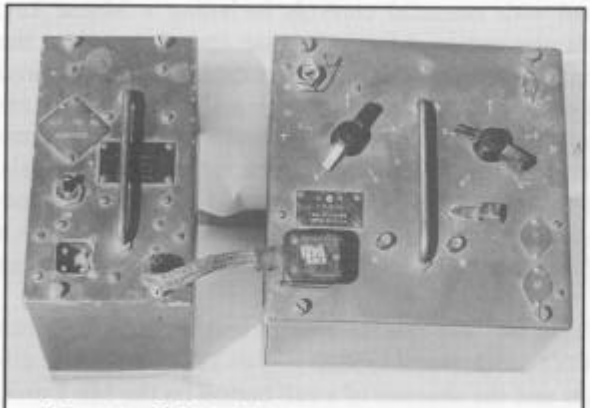


Fig. 22. British Mk II Eureka transponder

Fig. 23. Wireless Remote Control Unit "A "

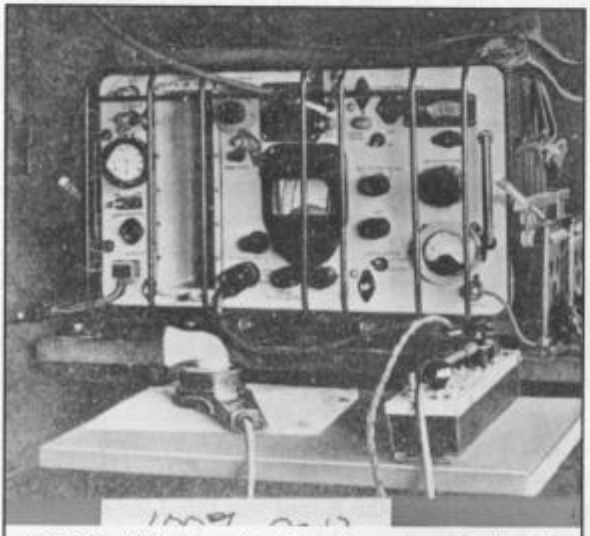


Fig. 24. Wireless Set No. 21 and control unit

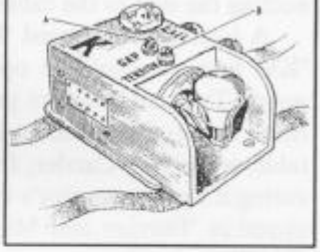
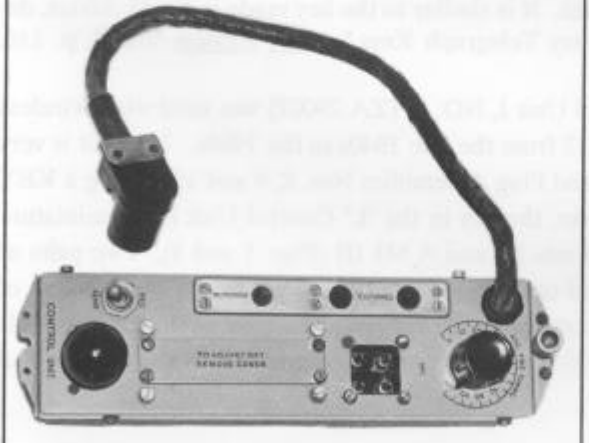


Fig. 25. Remote control units "K" (above) and "K," Mk 2 (below)



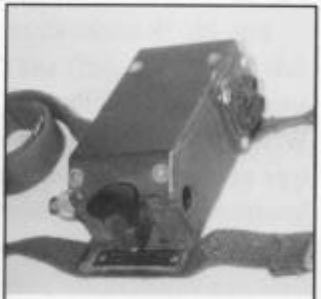


Fig. 26. Remote Control Unit L NO. 2

## VISUAL SIGNALLING

In the early part of WW I trench warfare, the British Signal Service used the "Lamp, Signalling" for visual Morse communication over relative short distances. Having wide dispersion of its rays, the lamp quickly drew the attention of the Germans, usually resulting in heavy shelling of the unfortunate signal-post. In 1915 a new lamp was devised by a Signal Division using an empty 4.5" shell, a spare motorcycle mirror and a small lamp, all mounted to slide for focusing, complete with an improvised sighting tube on top. This lamp appeared to be a great advance and was so successful that a model was sent to the Joseph Lucas Company at Birmingham to produce on a large scale.

**Fig. 27.** The "Lamp, Signalling, Daylight" was devised in WW I for short-range visual signalling. It was initially manufactured by Lucas Co., as marked on top of the key lever, hence the common name "Lucas Lamp." A second source was Arthur Lyon & Wrench Ltd. It saw wide use in the British Army throughout both world wars. It comprised basically a dry-battery operated lamp, normally mounted on a spike or tripod. The complete set and spare parts were carried in a wooden (later metal) box, covered with canvas and divided into two parts. The Morse key is fixed to the underside of one of the lids, which hinges back into a convenient position for operating. The lamp was connected with a flexible lead to two-pin sockets, mounted near the key. In Position 1, used for normal working, a resistance was inserted in the socket. When an extreme range is required or the battery was nearly run down, Position 2 was used. A number of variations of this instrument are recorded; the basic layout, however, has never changed.

**Fig. 28.** "Lamp, Signalling, Daylight, Short Range, Lightweight" using a standard KEY W.T. 8 AMP NO. 2 Mk. II (design 2A) without lever-protection cover. Late in WW II, a special lightweight version of the standard British Army short-range signalling lamp was made. The lamp could be mounted on a bayonet, used as a spike to secure the lamp in a fixed position, and controlled by an external Morse key mounted in the battery case. Alternatively, the lamp was hand-held, with the beam directed toward the other station by means of the sighting tube, and controlled by the Morse key ("pressel" switch Q) attached to the lamp.

**Fig. 29.** "Lamp, Signalling, Daylight, Short Range," WW II version. The drawing shows the lid of the lamp compartment in the carrying case, with alternative arrangements of parts. To ease manufacture and maintenance, use was made of a standard KEY W.T. 8 AMP NO. 2 (design 1B). In addition, two sockets J were available for connecting a lighting attachment.

**Fig. 30.** "E" combined oil and electric signal lamp, early WW I. The Morse key for the 2-½", 3.5-volt electric lamp is mounted in a dust-proof box, and stowed in a compartment in the oxidized-brass case. At the rear, in a second compartment, is a small oil lamp for reading. The case holds three "S" type batteries, and three spares in a third compartment.

**Fig. 31.** Signal lamp made by Eveready, with key mounted atop the case.

## WORLD WAR I RADIO

Keys were often built into early wireless transmitters intended for field use.

**Fig. 32.** "Wireless Trench Set, DC 50 watts," or "B.F." set, was a combined spark transmitter and receiver of very simple but rugged design. Used primarily

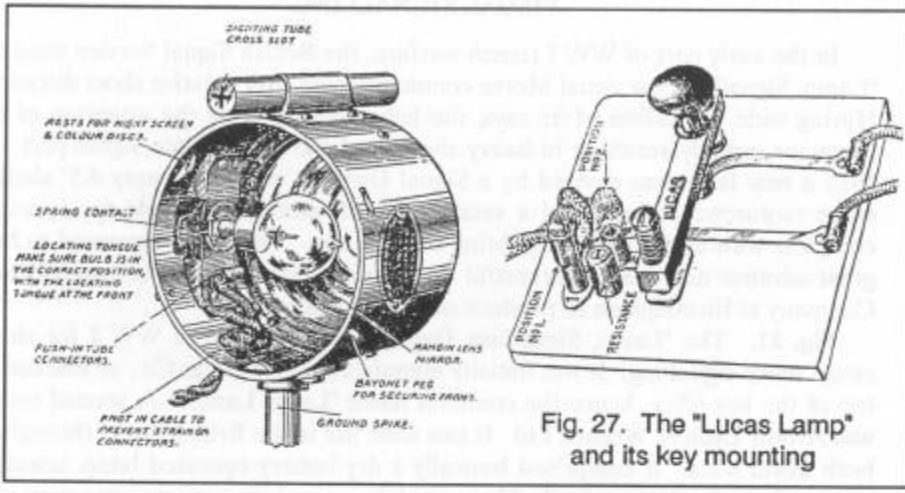

SIGHTING TUBE CROSS SLOT
SPRING CONTACT
LOCATING TONGUE MAKE SURE BULB IS IN THE CORRECT POSITION, WITH THE LOCATING TONGUE AT THE FRONT
PUSH-IN TUBE CONNECTORS.
MANGIN LENS MIRROR.
BAYONET PEG FOR SECURING FRONT.
KNOT IN CABLE TO PREVENT STRAIN ON CONNECTORS.
GROUND SPIKE.
POSITION NO 1.
LUCAS
POSITION NO 2.
RESISTANCE

Fig. 27. The "Lucas Lamp" and its key mounting

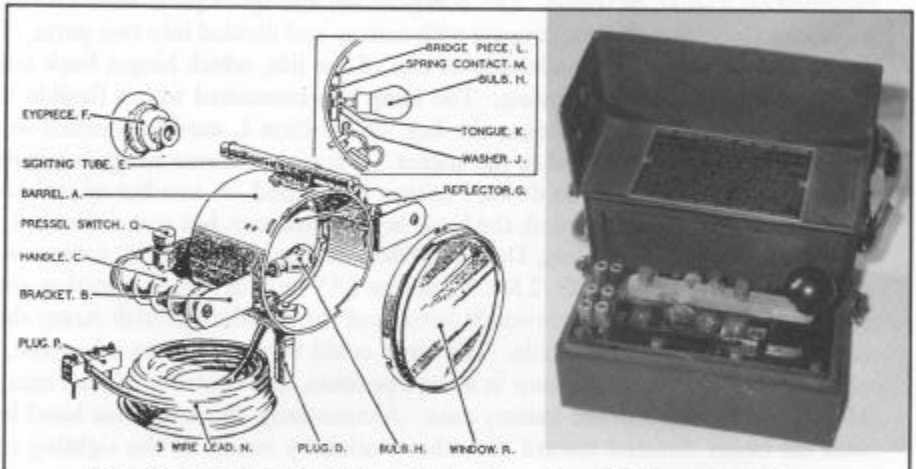



Fig. 28. "Lamp, Signaling, Daylight . . . " and its key mounting

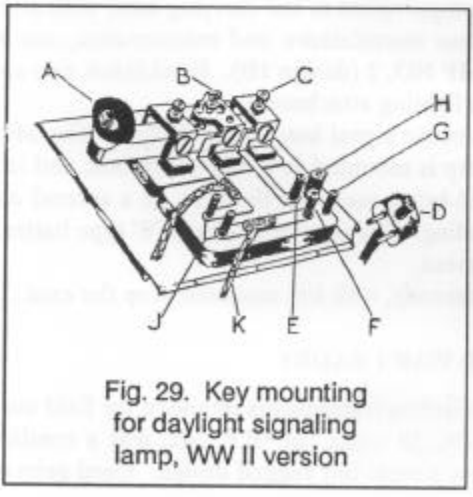



Fig. 29. Key mounting for daylight signaling lamp, WW II version

Fig. 30. The "E" combined oil and electric signal lamp

in front-line trenches, it operated on fixed wavelengths of 350, 450 and 550 meters (857, 667, and 545 kHz respectively). The key mounted on top of the ebonite control panel is of unusual design, having an extra contact protecting the carborundum detector during transmission.

Fig. 31. Signal lamp made by Eveready.

**Fig. 33.** German WW I spark set "K-Fuk-Gerät" (*Klein Funk Gerät*, or Small Radio Set) type AKS 58, made by Telefunken. This equipment has the same function as the British 50-watt Wireless Trench set (Fig. 32), finding use primarily in the front lines. Note the similarity of the layout and some of the controls to those of the British set. It had fixed transmitter wavelengths of 150, 225, and 300 meters (2000, 1333, and 1000 kHz respectively). The receiver tuned from 150 to 600 meters in three ranges, having a pyrite detector. The key of this set is remarkably small and could be operated when the cover was closed through a hole in the lid covered with waterproof canvas.

**Fig. 34.** Although the rugged and easy-to-operate spark radio sets remained in general use in the trenches, tube equipment appeared late in WW I on a limited scale. The transmitter unit of "W.T. Set, Trench, Continuous Wave, Mk III" saw service primarily with artillery observation parties. It covered the wavelengths of 450 to 2000 meters (150-667 kHz). The power input to two type "B" or AT25 tubes was 30 watts. The Morse key, officially known as "Key, WT, Folding" is mounted through the side of the waterproof cover, for use of the set with the lid closed.

**Fig. 35.** German WW I spark transmitter-receiver type "A," designed for use in single-seater fighters or artillery observation aircraft, having the Morse key mounted on top of the instrument. Later models used a key mounted on the aircraft's control column. The set was of contemporary simple-but-rugged design, manufactured by Telefunken around 1916-17. It was pre-set before flight and operated from 150 to 350 meters (857-2000 kHz).

**Fig. 36.** Keys WT 10 Amp. No. 1 and 2 were used with several types of CW radio station. The keys, having a spigoted lever, are similar, with an auxiliary contact added on the No. 2 key.

**Fig. 37.** WT Set, Field, 60-Watt CW. This transmitter is part of a CW radio station operating on the long waves, primary intended for rear communication. Transmitter and receiver were separate instruments; the transmitter had an input of 60 watts to two type "B" tubes in parallel. The Morse key is a "Key WT 10 Amp, No. 1," mounted directly on the ebonite baseboard near the tubes. Note the absence of the knob guard shown in Fig. 36. Virtually no protection is provided against a nasty shock from the open high-voltage connectors.

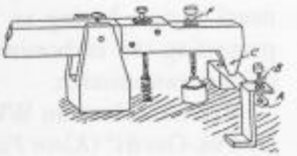


Fig. 32. "Wireless Trench Set, DC 50 Watts"

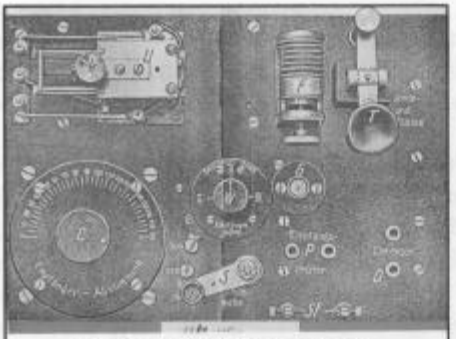


Fig. 33. AKS 58 spark set

Fig. 34. Transmitter of "W. T. Set, Trench, Continuous Wave, Mk III."

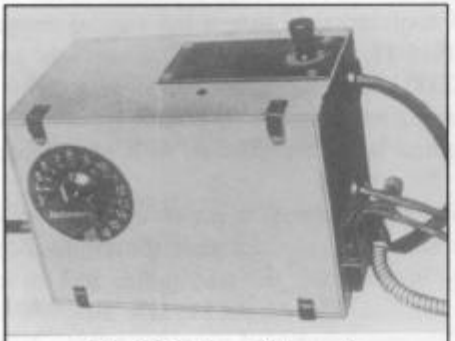


Fig. 35. Type "A" spark transmitter-receiver

**Fig. 38.** A rare original drawing of a Morse key used in Dutch Artillery observation aircraft during the years 1925-31. The key was normally mounted in the observer position and issued only during flights. It was therefore easily removable and fixed by a handle (*los*: loose, *vast*: fixed).

**Fig. 39.** Further evidence shows that this model key had previously been used for radio communication on German long-range Gotha bombers which appeared in bombing raids over London during 1917. The type R set (R: *Riesenflugzeug*, or "giant airplane"), shown here in the aircraft's radio cabin, was made by Telefunken. It comprised a 500-watt spark transmitter and crystal receiver. Below the table is a four-tube type EV136 audio amplifier for the receiver.

**Fig. 40.** Wireless Telegraph Set, 120 Watt, Mk I. This unit was developed in WW I but saw service only after 1919. It was intended for medium-range communication and operated on wavelengths between 600 and 8000 meters (37.5-500 kHz) with a nominal range of 200 miles. Mounted in a wooden transit case, it comprised a transmitter unit (left) with two "B" tubes; rectifier unit (center left) with two "U2" tubes; detector-amplifier "C," Mk. IV (center right) with three "A" tubes; and the receiver RF tuner (right). The key, visible in front of the "C" Mk IV amplifier, is a Key, WT 10 Amp. No. 2.

**Fig. 41.** Transmitter of British "W/T Set, C, Mk I" (1924) showing KEY, S.C. [single current], 4 AMP, in front and close-up views. The key is mounted on a base for easy replacement. It may also be found on other British Army radios of the period. The "C" set was primarily used for CW communication at brigade and division level. It operated between 650 and 2000 meters (150-462 kHz). The transmitter output tube shown in the photo is an AT50. A later Mk II version of the set, introduced about 1925-26, uses a KEY W.T. 8 AMP (design 1A).

## WIRELINE EQUIPMENT

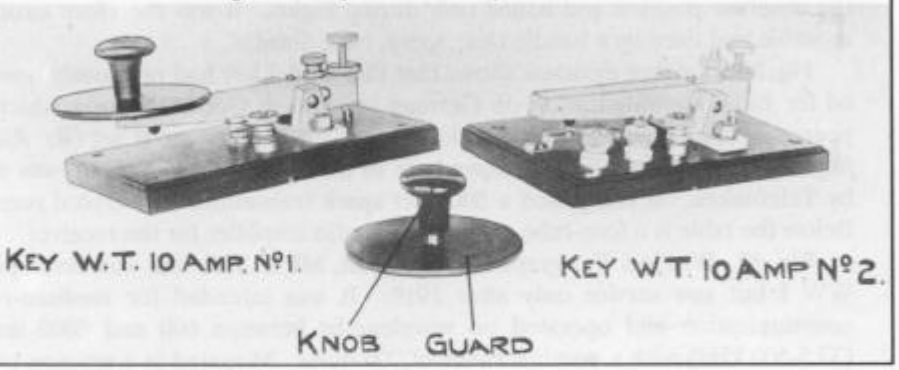
### Telephones

Early field telephones were inefficient and were suitable only for relative short-range working. For operation over longer distances, a buzzer telegraph set was often incorporated into the telephone set, having the advantage of giving audible signals over very bad lines.

**Fig. 42.** The Telephone D Mk III* was developed in WW I and saw wide use well into WW II. It combines a telephone set with a buzzer telegraph. The DIII* instrument (sometimes affectionately known as "Don three star" from the British phonetic alphabet of the time) shown in the picture with leather case and handset removed, was manufactured as late as 1937 by AT&E Co. Ltd. At that time it was badly outdated, lacking both a magneto call and an anti-sidetone bridge circuit. The Morse key, shown between two terminals, is a miniature type used for both signalling and making a buzzer call to the switchboard. Two batteries are contained in the compartment behind the key. It can call only by buzzer, giving visual indication to a switchboard U.C. ("Universal Call"), which can be called by both magneto and buzzer.

**Figs. 43A and 43B.** Telephone set D Mk V was developed in the late 1930s to replace the D Mk III for use in forward formations. It had a range of about 15 miles for speech and 25 miles using Morse buzzer telegraphy. The Morse key on the D Mk V is a miniature type known as "KEY SIGNALLING NO. 1." The

Fig. 36. Keys WT 10 Amp. No. 1 and 2



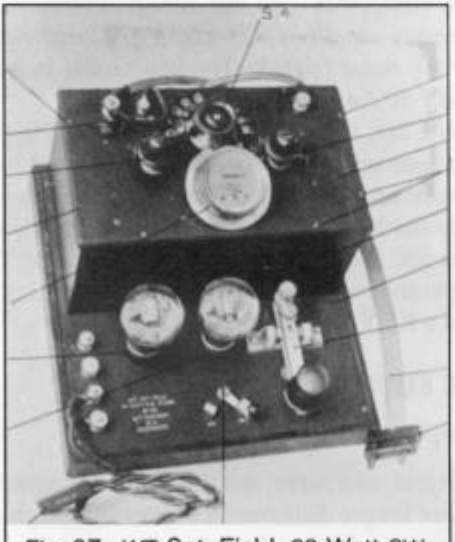



Fig. 37. WT Set, Field, 60-Watt CW

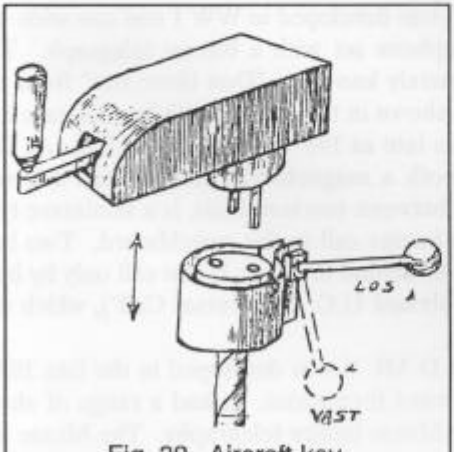



Fig. 38. Aircraft key

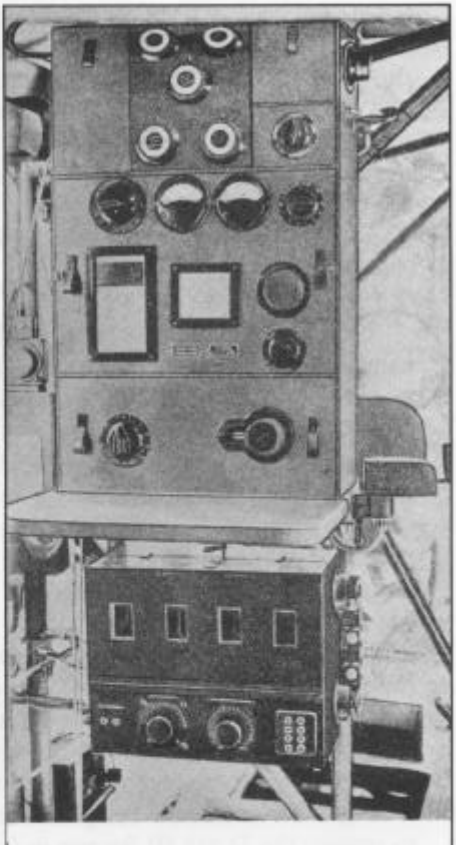


Fig. 39. Radio cabin, Gotha bomber (note key on right)

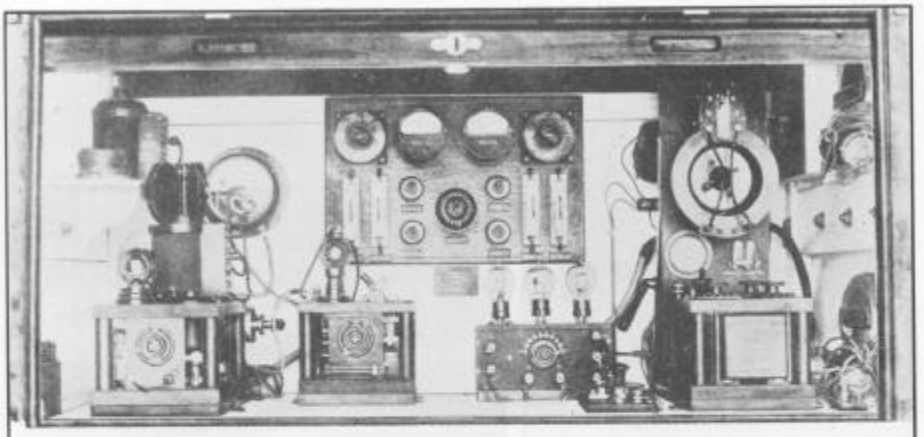


Fig. 40. Wireless Telegraph Set, 120 Watt, Mk I

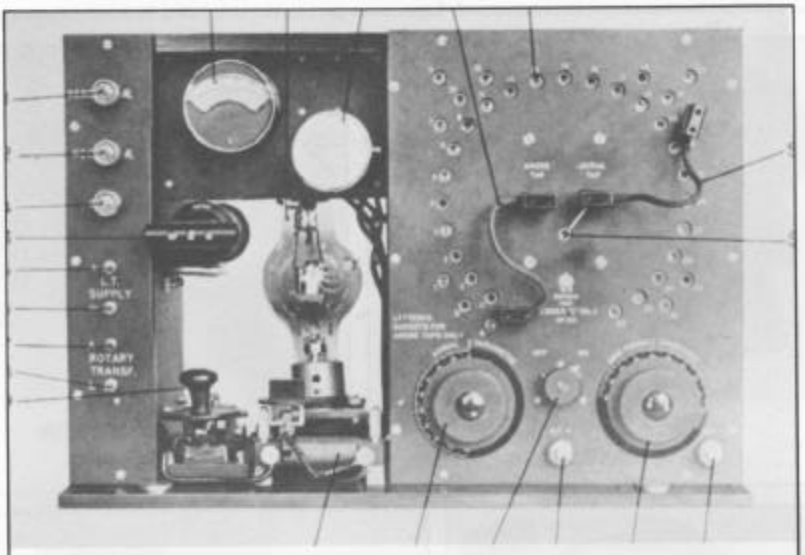


Fig. 41. "W/T Set, C, Mk I"

Fig. 42. D Mk III*
field telephone

Fig. 43A. D Mk V
field telephone

Fig. 43B. Key in
D Mk V telephone

Fig. 44. Japanese
field telephone

Fig. 45. British "power buzzer"

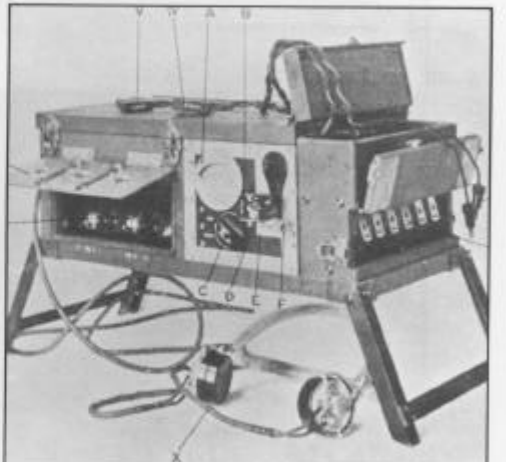


Fig. 46. Power buzzer amplifier

key is interesting mechanically, having two metal levers separated by a bakelite insulation piece. It has a pair of mark contacts and a single space contact. The "mushroom" type knob is similar to the one used on the KEY WT 2 AMP.

**Fig. 44.** Japanese field telephone of WW II pattern, showing buzzer Morse key. The telephone handset has the microphone and receiver back-to-back at the listening end. On unscrewing the cap, the earphone assembly comes out and then the microphone capsule. A second receiver was also issued.

### The Power Buzzer

Water or the earth can be used as a conductor for electricity. At a very early stage in the history of electric signalling, ground return was employed in telegraph circuits. Experiments with signalling through the earth without wires started as early as 1842 and continued until the advent of radio telegraphy at the turn of the century. However, at the WW I front, where wire lines and even radio aerials could not be maintained due to heavy shellfire, the system attracted renewed interest. The advent of tube amplifiers made it possible to attain ranges and results unattainable before the war. Communication was established over comparative long ranges by using two well separated ground spikes, connected by insulated cables to a high-power AC or interrupted-DC source as transmitter and a sensitive AF amplifier connected similarly on the receiving side. The French introduced this system, Telegraphie Par le Sol (TPS), soon to be adopted by the Allies, including the U. S. Signal Corps. The system was used to the same extent by the German Signal Service.

**Fig. 45.** British "Power Buzzer." It was mounted in a wooden case covered with canvas. The heavy-duty buzzer (T) provided approximately 80-100 volts interrupted DC. The Morse key (A-H-J), having a hinged extension, is shown in transit position. In operational use the lid is closed, the key extending outside the lid through a cutout. The system provided only one-way signalling, which was considered a heavy drawback due to lack of indication that a message had been received. Later combined Power Buzzer/Amplifier sets were developed which allowed two-way working.

**Fig. 46.** Power Buzzer Amplifier. This was a self-contained earth-current instrument and further development of the power buzzer in Fig. 45. It comprised a combined power buzzer and three-tube audio amplifier, providing two-way signalling. The folding Morse key (E), seen in the picture in working position on the right of the front panel, is similar to the key shown in Fig. 34.

### Vibrator or Buzzer Telegraph

Vibrator and buzzer telegraphs, operating with interrupted DC, were intensively used by the British (and other) armies in the 1890s up the end of WW I for their great ability to signal through leaky or broken lines. Their use (including the buzzer mode of field telephones) within 3000 meters of the front lines ("Danger Zone") was forbidden in 1915 due to danger of overhearing and interception by the enemy.

**Fig. 47.** Transmitter Vibrating Mk IV (similar in operation to the US "Buzzer, Service," "Cavalry Buzzer," etc.).

Fig. 47. Transmitter Vibrating Mk IV

Fig. 48. Fullerphone Mk I*

Fig. 49. "Apparado da Campo . . "

Fig. 50. Fullerphone Mk V

Fig. 51.
Sutel 40

## The Fullerphone

As a technical countermeasure against enemy interception of line communication, caused by induction or conduction, Captain (later Major General) A. C. Fuller invented the Fullerphone in 1915. It is a DC telegraph; the Morse signals are made audible at the receiving side by an interrupter or "buzzer-chopper" and headphones. The Fullerphone was an instant success and remained in use with the British well after WW II.

Not only the British used Fullerphones; in other armies the threat of line overhearing and interception was also realized. Independently, and at virtually the same time, similar instruments were devised: in Germany, the "Utel" (*Unabhörbarer Telegraph*, or Non-interceptable Telegraph); in Italy, the "*apparado da Campo per telegrafia inintercettabile*" or "apparatus, field-telegraph, non-interceptable."

**Fig. 48.** Fullerphone Mk I*. This set was manufactured by Siemens Bros. in 1916. The Morse key, which is fixed-mounted on the control panel of the instrument, is very similar to the key used with the Transmitter, Vibrating Mk IV (Fig. 47).

**Fig. 49.** "Apparado da Campo per telegrafia inintercettabile."

**Fig. 50.** Fullerphone Mk V. This model is a tropicalized version of the standard 1939 Mk IV type. DC earth currents, interfering with the signalling, are nulled-out by means of the potentiometer and reversing key on the front panel. In order to meet tropical test requirements, dome-shaped silver-nickel contacts are used instead of the flat tungsten contacts on the KEY W.T. 8 AMP No. 2 Mk II (design 2A) used with the Mk IV Fullerphone. The dome shape increased the contact pressure, which was advantageous, as the current through the key of a Fullerphone is only about 1 mA. Since this key would not be suitable for heavy-current use, it was cataloged "KEY SIGNALLING NO. 2," having Army stores vocabulary number YA 6897. Note the absence of the lever cover.

**Fig. 51.** German Sutel 40 (*Summer Telegraph*, or "Buzzer Telegraph"). This was a development of the WW I German "Utel," primarily replacing the awkward mechanical buzzer-interrupter by a cunningly designed electronic audio-frequency generator. The circuit operated with a single space-charge tube, powered from a dry battery of only nine volts. Due to line capacitance the Morse signals tend to "blur," reducing the signalling speed on long lines to a rather slow 5 to 7 WPM. The key is a common German "mouse" model, encapsulated in a dust-proof bakelite cover, mounted on a steel base plate. When not in use, it was fixed in the lid of the fiber case, which is very similar to that used with the standard Model 33 field telephone. The set saw limited use during WW II.

**Figs. 52 and 53.** Two examples of German keys used in WW II, affectionately known as "mouse" keys, long before the later-type (computer) mouse. Both were used primarily with portable communication equipment: the Sutel and such radios as Fu d2 and Torn Fu g. They were also issued with agents' transmitters. They are virtually identical, the one on the left having a longer lever arm and a round knob. Both are marked TKP (*Taste Klein P*, or "Key, Small, P").

Figs. 52 and 53. Two German "mouse" keys

Fig. 54. Wireless Set No. 46

Fig. 55. Radio Control Box BC-451-A

Fig. 56. Experimental Wireless Sender X66 (also see Fig. 57)

## MISCELLANEOUS AND WARSAW PACT RADIO

### WW II Keys

**Fig. 54.** British Wireless Set No. 46. It had an internal Morse key ("Press To Send"), located on the front panel, which also functioned as transmit/receive button on R/T. The No. 46 set, developed in 1941, was intended primarily for communication in beach-assault landings by Combined Operations Command. It was very strongly built and fully waterproof. Crystal control of both receiver and transmitter was employed to avoid time-consuming tuning when establishing vital communication in initial stages of landings. Three channels were available in one of four bands between 3.4 and 9.1 MHz, delivering 1-½ watt RF. Due to physical limits of the key, the maximum speed was restricted to 12 WPM.

**Fig. 55.** Radio Control Box BC-451-A. Part of the US Army Air Force SCR-274N "command" set, it was used for controlling up to four transmitters. It had an auxiliary Morse key on top. This key-equipped control box resembled such similar-shaped control boxes as BC-AT-232 for the Army SCR-183/283 and CW-23097 for the Navy GF-11 set.

**Fig. 56.** Experimental Wireless Sender X66. This was a development model for long-range airborne "rear link" CW communication. The internal Morse key, mounted in the center of the front panel, is obviously the miniature model shown in Figs. 1 and 3 without lever cover.

**Fig. 57.** Reception Set R109A (left) and Wireless Sender No. 66 (right) in use. Apparently the key construction in the X66 was impractical and in the final model, the internal key was discarded. Instead, a British "KEY AND PLUG ASSEMBLY NO. 9" was issued, comprising one of the versions of the standard KEY WT, 8 AMP, No. 2, in a metal protection cover (see Fig. 97). The photo shows a British Airborne signaller using a "rear-link" HF set comprising Reception Set R109A and Wireless Sender No. 76. Faintly visible, strapped to the operator's thigh, is a "KEY AND PLUG ASSEMBLY NO. 9."

**Fig. 58.** Morse key J-48-A This unit was used with US Army radio set SCR-284-A, here shown installed in Car, ½ Track, M2. It was fixed on the lid of the field case for the BC-654-A transceiver, which provided a suitable operating table when operational. The J-48-A assembly shown contains a J-38 type Morse key.

**Fig. 59.** Key and T-R switch box for US Marine Corps TBY portable VHF transceiver. This unit is shown with its tight-fitting rubber cover pulled back. In operation the box clipped on top of the transceiver case or to any convenient canvas strap.

**Fig. 60.** "KEY AND PLUG ASSEMBLY NO. 17" (ZA 25381). It was used with the Wireless Set No. 42. It appears to be very fragile, having a thin bakelite case. A send-receive switch is incorporated and can be seen on the upper part on the side of the case. The miniature-type Morse key is made from pressed steel.

### Postwar Miniature Keys

An example of a postwar miniature key is the Key, Telegraph, Lightweight (Aust.), No. 1. This type was used with lightweight jungle patrol radios, usually working on HF, e. g., the Australian Wireless Station A510. The key is completely sealed, having a fixed adjustment of 0.013" travel and 10-ounce pressure.

Fig. 57. Reception Set R109A and Wireless Sender No. 76

Fig. 58. SCR-284-A radio, J-48-A key

Fig. 59. Key for TBY transceiver

Fig. 60. "KEY AND PLUG ASSEMBLY NO. 17 "

Grooves at the bottom of the key, corresponding with a gateway on the side of the transmitter, enable the key to be attached to the set.

This key model was quite common and saw use with British HF man-pack radios of the 1950s through 1970s (e. g., Station Radio A13 and A14). A strap at the key base provided for fixing it on the operator's knee.

**Fig. 61.** "Key, Telegraph, Lightweight (Aust.) No. 1." The case is made of light brown plastic, bearing the maker's initials and date of manufacture: TSE(W)9-2 -1956- . It was used with Wireless Station A510 (Aust), an HF man-pack set with separate transmitter and receiver carried in canvas pouches. The transmitter unit is shown in the picture.

**Fig. 62.** A similar lightweight key in use by a British signaller operating a Station Radio A13. The second signaller is operating a hand generator, float-charging the batteries. Designated "Telegraph Key Assembly, BCC type B8000-196," the key has a black case with inscription of the NATO stock number 5805-99-949-9618. The dark-green canvas strap is permanently attached.

**Fig. 63.** British Patrol Station Radio A16. The lightweight HF patrol SR A16 (UK/PRC-316) is a compact, simple-to-operate transceiver, developed by the Signals Research and Development Establishment (SRDE) in the 1960s. It was intended for operation in dense jungle and for long-range communications up to 800 km for patrols or special-operations parties. It provides 45 crystal-controlled channels in the 2-7 MHz band with an RF output of approximately 4 watts. The complete self-contained set weighs only about 4 kg. The Morse key is built into the set, fixed at top right of the control panel. Although the set was developed primarily for CW working, short-range (AM) radiotelephone communication was included. A remarkable feature is an engraved plate on top of the set with the international Morse code, guiding inexperienced patrol members in the transmission of low-speed Morse in an emergency.

**Fig. 64.** British Station Radio A16 (UK/PRC-316) in operational use. Note the employment of a dipole wire aerial, directly connected to the set's aerial terminals.

**Fig. 65.** RAF key assembly "CONTROL REMOTE GROUND STATION TYPE D," Air Ministry Ref No 10J/65. This unit was used for keying fixed transmitters from a remote point (e. g., an airfield control tower). The key on the unit is a "KEY MORSE TYPE D," Air Ministry Ref No 10F/7373. Note the use of civilian-type mains switches for transmitter control.

### Warsaw Pact Radio

**Fig. 66.** USSR Morse key issued with type R104M pack/vehicle station (variation 1). The R104M set operates from 1.5 to 4.25 MHz, delivering 3.5 W CW or 1 W AM on low power, and 20 W / 10 W on high power. Developed in the early 1950s, the set has been used extensively in the USSR and its satellite countries. Indications are that it is still in operational use in some countries. In operation, the Morse key is clipped on top of the lid of the power-supply/battery case. When not wanted it is stowed inside the lid. The R104M in the photograph was used in the former German Democratic Republic and consequently has inscriptions in German.

**Figs. 67 and 68.** Additional USSR keys for the R104M radio. Variation 2 (left) resembles the US J-38 in many details. Variation 3 (right), date of manu-

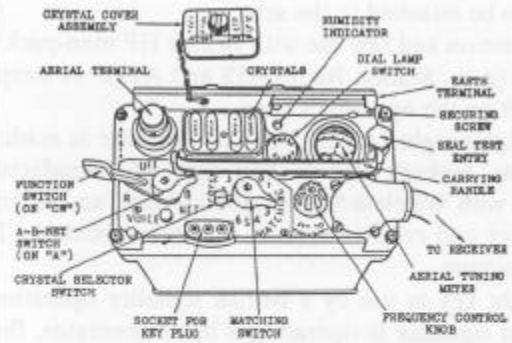


Fig. 61.
Wireless Station A510 (Aust) and "Key, Telegraph, Lightweight (Aust) No. 1 "

Fig. 62. "Telegraph Key Assembly, BCC type B8000-196" and Station Radio A13.

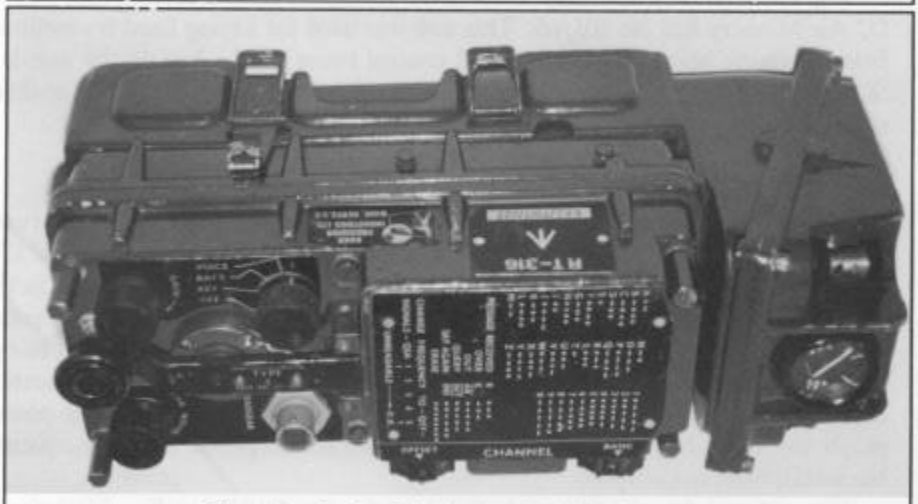


Fig. 63. Station Radio A16 (UK/PRC-316)

facture 1986, is an interesting miniature key. However, it is awkward to handle and not crafted well.

**Fig. 69.** USSR "universal" model Morse key, variation 1. Production date 9/85, manufactured by MPI (Mashpriborintorg). These keys have been offered brand-new boxed. The key is made of bakelite and brass, probably intended for replacement or as a general-purpose part.

**Fig. 70.** USSR "universal" Morse key, variation 2, marked 3TA (ZTA) on top of bakelite cover. This key is much better engineered than variation 1, e. g., having a tension screw similar to the Junker key system. It has an insulated lever. Two metal strips are fixed on the bottom of the key for sliding it on a table of the radio vehicle.

**Fig. 71.** USSR Morse key for radio type 10 RT, the standard tank and armored-vehicle HF set of the 1950s.

**Fig. 72.** USSR key used with vehicle-mounted high-power radio stations such as the R102M 900-watt system, made about 1985. The key has a dust-proof aluminum cover and a radio-interference filter in the base.

**Fig. 73.** Morse key for SSB transceiver SEG 15D. The key resembles the well known Junker key but lacks its typical numbered tension screw. Its case is dust-protective but by no means waterproof, as several rubber gaskets do not appear to seal well. The key is mounted on a heavy steel base-plate. Note the similarity of connector type to the one used with the British lightweight key (Fig. 62).

**Fig. 74.** The SEG 15D transceiver, made in the former German Democratic Republic by VEB "RFT" (VEB: *Volks Eigenes Betrieb*, or "People's Own Factory") of East Berlin. This 1970s fully transistorized, frequency-synthesized transceiver was exported to many countries, including North Vietnam.

**Fig. 75.** A fascinating key used with the Czech R4 HF field radio set. The transmit-receive switch is incorporated in the key lever. Transfer is effected by putting the lever down from the upper "receive" position to "stand-by." In that position the key operates as a normal Morse key. The key is well engineered, having a dust-proof cover with a properly closing gasket. Note a pair of safety contacts on front of the key protecting the operator from coming into contact with high voltage if opening the key cover.

**Fig. 76.** "Morsetaste K 64" (Morse key model K 64), used primarily with

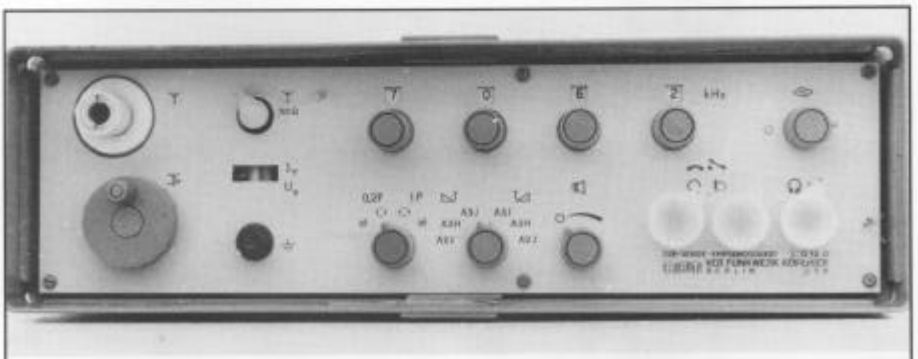


Fig. 74. Transceiver SEG 15D

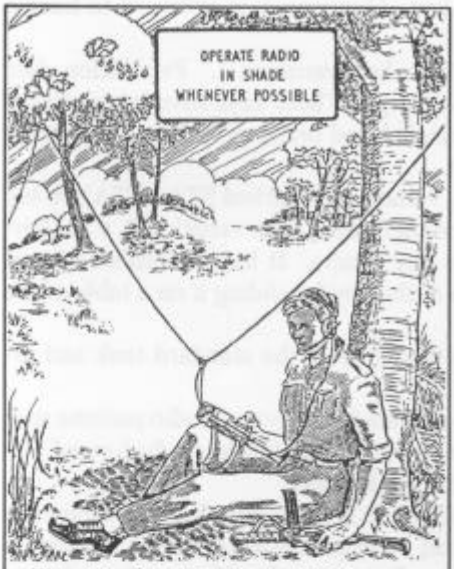



Fig. 64. Station Radio A16 in use

Fig. 65. "CONTROL REMOTE GROUND STATION TYPE D"

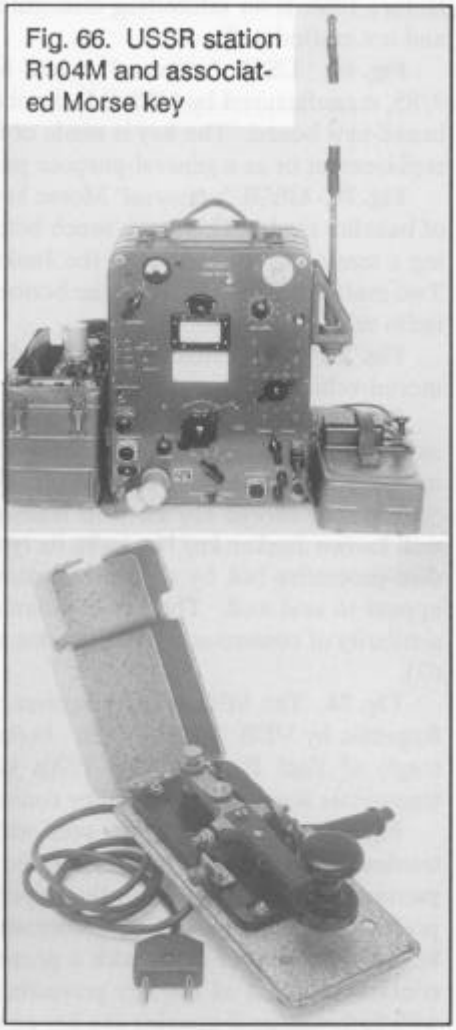
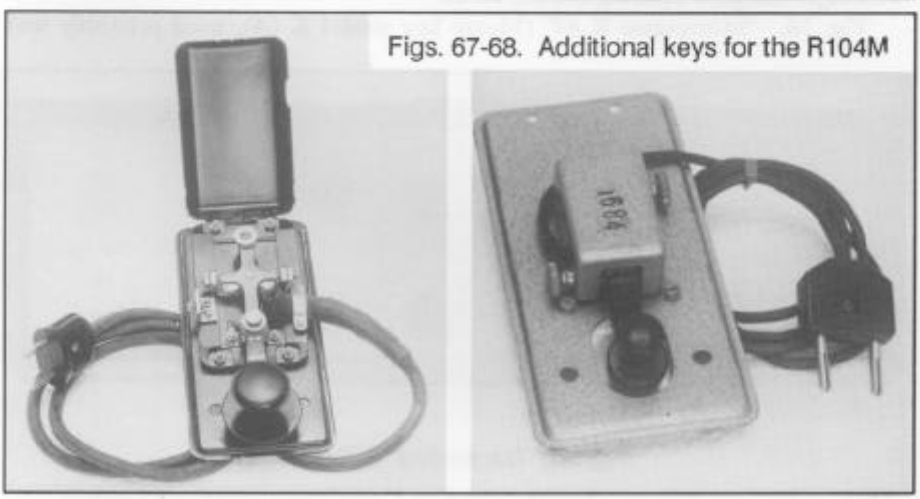


Fig. 66. USSR station R104M and associated Morse key



Figs. 67-68. Additional keys for the R104M

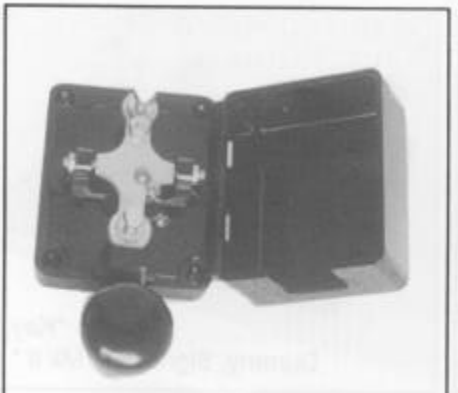


Fig. 69. USSR "universal" key, variation 1

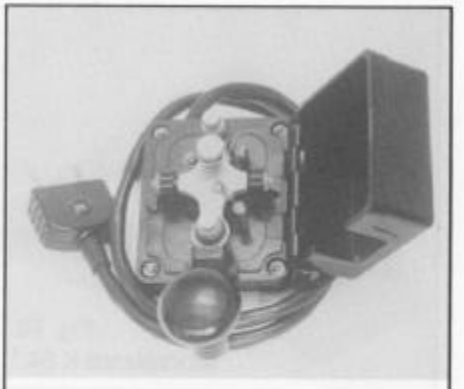


Fig. 70. USSR "universal" key, variation 2

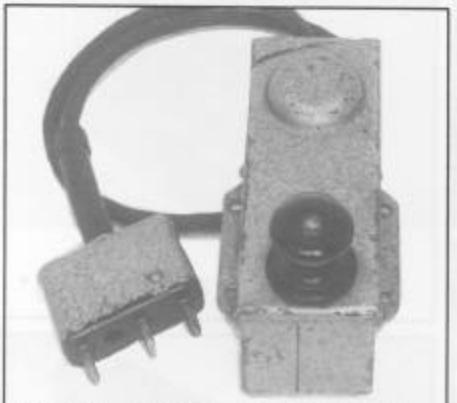


Fig. 71. USSR key for 10 RT radio

Fig. 72. USSR vehicular key

Fig. 73. Key for SEG 15D

Fig. 75. Key for Czech R4 field set

Fig. 76.
"Morsetaste K 64."

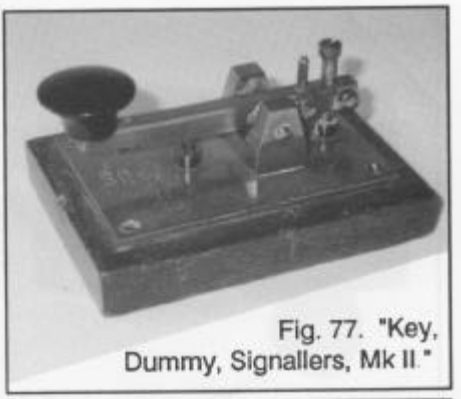


Fig. 77. "Key, Dummy, Signallers, Mk II."

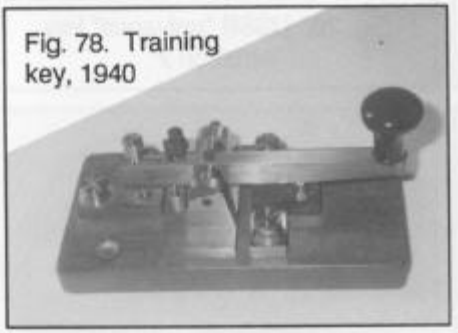


Fig. 78. Training key, 1940

Fig. 79. "Buzzer Signal Training"

Fig. 80. RAF "BUZZER PRACTICE."

Fig. 81.
"Buzzer Signal Training," 1940

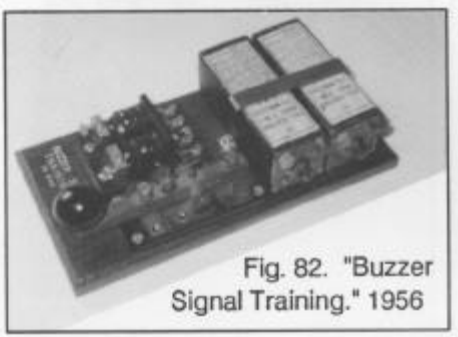


Fig. 82. "Buzzer Signal Training." 1956

Fig. 83. RAF 10F/702 dummy key

GDR-manufactured radios Fu 1 and Fu 10, but also the R104M (fitted with the metal base plate as pictured). This key was made by VEB "KFZ-Bedarf," Leipzig, in the German Democratic Republic. It is not a masterpiece of craftsmanship - it appears rather fragile, with most of the parts molded in bakelite.

## TRAINING KEYS

To instruct new radio operators and air crewmen in Morse techniques, training keys and associated equipment were naturally required.

**Fig. 77.** "Key, Dummy, Signallers, Mk II," made in 1939 by DOM Loose Leaf Co. Ltd. "A dummy key is issued for instructional purposes. In order that beginners may acquire the true rhythm of Morse signals from the start, the initial indoor instruction both in reading and sending should be concentrated on this instrument" (Signal Training, -All Arms- , 1932).

**Fig. 78.** Training Morse key, 1940, used by Air Training Corps for pre-entry training for the RAF during WW II.

**Fig. 79.** "Buzzer Signal Training." This is a self-contained Morse training unit comprising a key, buzzer, and battery, mounted on a wooden base. "Instruction in reading a buzzer should not be started until the beginners are proficient in all signals sent on the dummy key, at 4 words a minute" (Signal Training, -All Arms- , 1932).

**Fig. 80.** RAF "BUZZER PRACTICE," Air Ministry Ref No 10F/4067. It bears a remarkable resemblance to the Army "Buzzer Signal Training" in the previous figure. The Morse key, however, is slightly different, having a thicker lever and no knob guard.

**Fig. 81.** "Buzzer Signal Training," 1940. This buzzer has an unusual metal base. The Morse key is a KEY W/T 8 AMP, No. 2 Mk III (design 2C) molded of bakelite.

**Fig. 82.** "Buzzer Signal Training," 1956, YA 2588. The Morse key is a KEY W/T 8 AMP, No. 2, Mk II (design 2A) with metal lever.

**Fig. 83.** RAF, Air Ministry Ref. No. 10F/702 key assembly, was used for instructional purposes. The Morse code is molded into the bakelite key base. The key has obviously a civil background and reads MADE IN ENGLAND REG DESIGN on the base.

**Fig. 84.** "Operator Control Unit, Mk I" is part of the "Training Set, Universal, Wireless, No. 1." The set was developed for training operators in Morse sending and reading and in radiotelephone communication. It was used for teaching a class of up to 36 operators, arranged in six groups. Each operator has headphones and a microphone plugged into the Operator Control Unit. A KEY W.T. 8 AMP NO. 2 (design 1B in this drawing) is fitted in the Unit, which connects to the instructor's set by a cable. The difference between the Mk 1 and Mk 2 units is in the plugs and sockets used for interconnection.

## THE KEY W.T. 8 AMP

This remarkable Morse key, easily recognized by its "mushroom" type knob, was employed as standard with numerous types of signalling equipment throughout the British and Commonwealth armies. Designed in the 1920s, its general construction was changed drastically prior to and during World War II into the

Mk II and Mk III models, having a simpler construction leading to ease production. The keys are recorded as having been manufactured by numerous manufacturers, including those in the USA and Commonwealth countries. Although the physical size remained virtually unaltered, allowing interchanging, its mechanical strength decreased, especially with the molded-bakelite models and those having a die-cast frame and lever.

The KEY W.T. 8 AMP can be classified into two basic designs and sub-divided into a number of principal variations. The classification of the variations is carried out in chronological order as far as could be traced. In the captions, the name or identification normally found on the key or KEY AND PLUG ASSEMBLY is printed in capitals between quotation marks.

Manufacturers made a large number of minor variations in the construction of the keys. As these did not led to drastic changes, they were not considered for inclusion in this paper.

An additional feature was the addition of a bakelite cover over the key lever, protecting the operator from coming into contact with the high voltage.

**Design No. 1**

The initial and No. 2 prewar patterns had their contacts placed above the key lever. The marking (normally closed) contact is at the back and the spacing contact is the front stop. The key is made of brass, having an ebonite (later bakelite) base. The general construction is rather heavy, with three bridges bearing the fixed contacts.

**DRAWING 1.** Variations of Design No. 1, showing the initial "KEY W.T. 8 AMPS" (Variation A), used with radio sets A Mk I* and C Mk II about 1925-26. Note the different type of center bridge. The "KEY W.T. 8 AMP No 2" (Variation B) is recorded as having been used as early as 1927, fitted in later-production radio sets of the A and C patterns. A 1930s version (Variation C), shown at the bottom, had a different and simpler spring-tension adjuster system.

**Fig. 85.** Design 1, variation B, "KEY W.T. 8 AMP No. 2," the early model.

**Fig. 86.** Design 1, variation C, "KEY W.T. 8 AMP No. 2," later model. The spring-tension adjuster is simplified. This type of spring adjuster was used on all the later design 1 variations and exclusively on design 2 variations.

**USA**

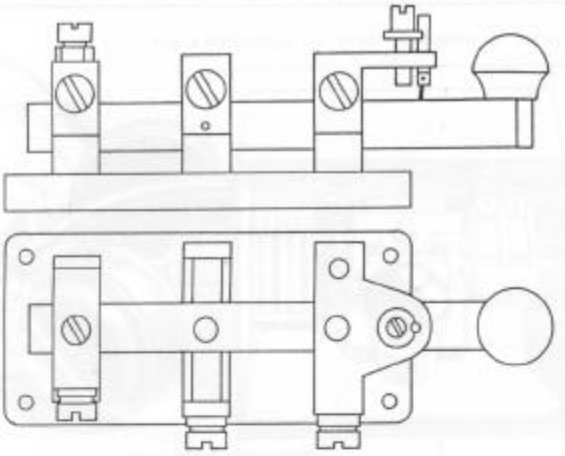
The KEY W.T. 8 AMP was made in the USA, primarily for issue with the US-produced Wireless Set No. 19 Mk II. The design of the key, made by Bunnell to specifications of the British No. 2 key, differed slightly. It is essentially a design 1, version C key, having a front bridge stop but no space contact. The key was mounted exclusively in a version of the "Key and Plug Assembly No. 9" (Fig. 100). Many of the lever covers were made of Ebonite.

**Fig. 87.** Design 1, variation D, "J. H. BUNNELL & CO. NEW YORK, U. S. A." Note the different style of key knob and the absence of a front (space) contact.

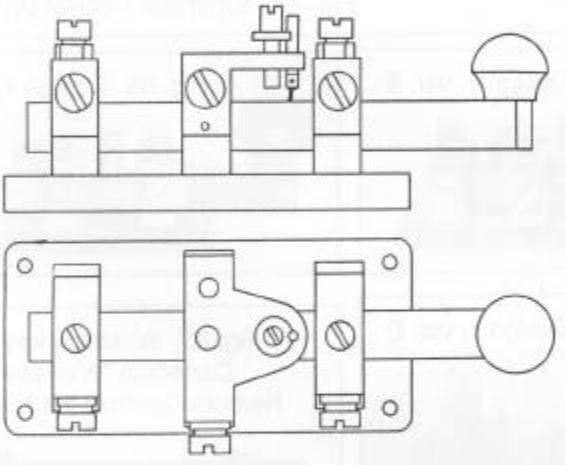
**Canada**

Signal equipment in Canada was, especially in the early war years, based on British designs manufactured locally (and sub-contracted in the USA). This resulted in interesting variations of the KEY W.T. 8 AMP No. 2.

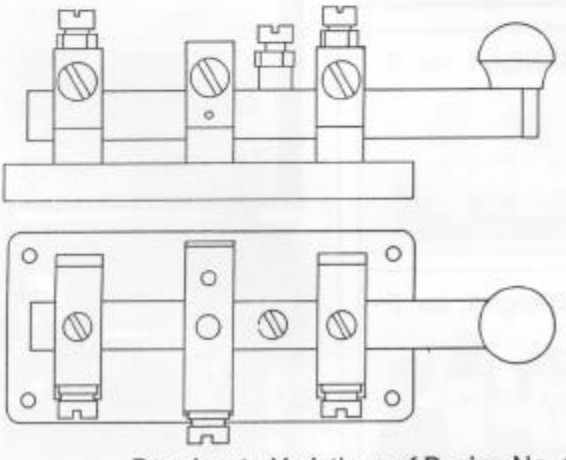
**Fig. 88.** Design 1, variation E, "KEY W.T. 8 AMP No. 2," made by Northern



1A



1B



1C

Drawing 1. Variations of Design No. 1

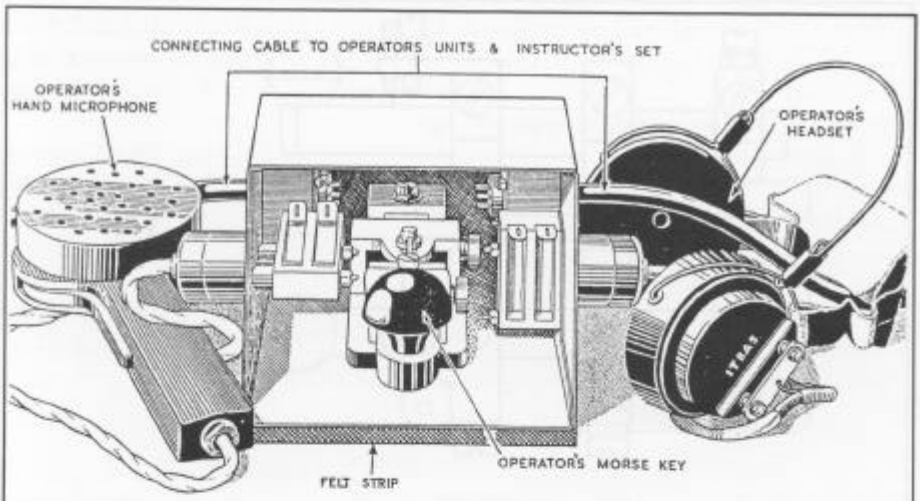



Fig. 84. "Operator Control Unit, Mk I "

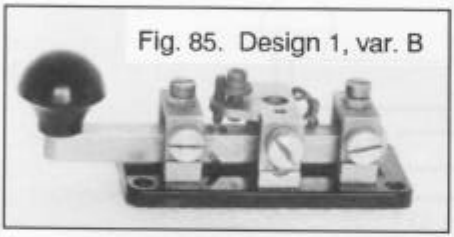


Fig. 85. Design 1, var. B

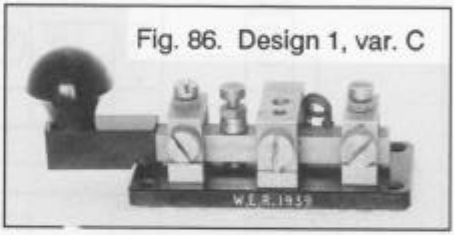


Fig. 86. Design 1, var. C

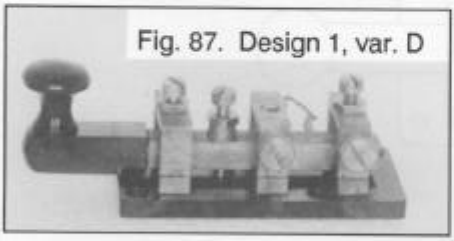


Fig. 87. Design 1, var. D

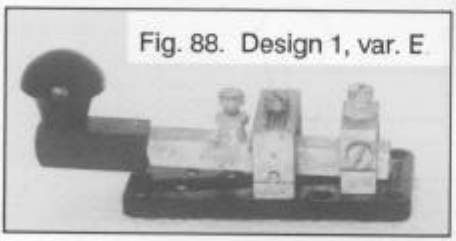


Fig. 88. Design 1, var. E

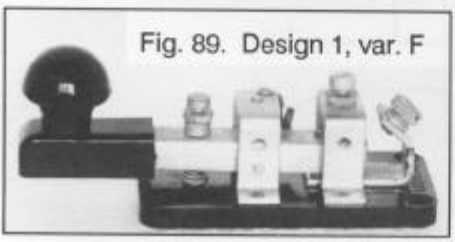


Fig. 89. Design 1, var. F

Fig. 90. Westclox key in Canadian "Wireless Remote Control Unit No. 1 "

Electric Co. It was used exclusively in KEY AND PLUG ASSEMBLY NO. 9 (Fig. 95) issued with Canadian Wireless Set No. 19 Mk II. Note the absence of the front stop bridge. It had no braid connecting wire between the lever and bridge, which could eventually led to poor contact.

**Fig. 89.** Design 1, variation F, Canadian "WESTCLOX" key. The Canadians used the Westclox key exclusively in many of their later WW II signal equipments, including a version of "Key and Plug Assembly No. 9" (Fig. 102). The key is made along the British design 1, variation C, but differs considerably, having a lever and general construction of pressed steel.

**Fig. 90.** "WESTCLOX" key mounted in Canadian "Wireless Remote Control Unit No. 1." The unit was used for remote control of Wireless Sets Nos. 9 (Can), 19 (Can), and 52 (Can). Note the absence of a cover for the lever.

### Design No. 2

The KEY W.T. 8 AMP No. 2 Mk II model (variation A) is of a simpler construction, having the space contact in the front. The fixed contacts are embedded in the bakelite base. A later version (variation B) uses a molded bakelite lever. Its bakelite base is similar to that of earlier Variation A keys.

The No. 2 Mk III model (variation C) was, as far as can be traced, made only in an all-molded-bakelite construction. The bakelite levers of the Mk II and Mk III models are basically similar; the construction of the base was altered.

**Fig. 91.** Design 2, Variation A, "KEY W.T. 8 AMP No. 2 Mk II." Note the basic difference: design 1 had the space contact in the rear, using three brass bridges, while design 2 keys had the space contact in the front, with the fixed contacts fitted in the base.

**Fig. 92.** Design 2, Variation B, "KEY W.T. 8 AMP No. 2 Mk II" with molded bakelite lever. The bakelite base is similar to that of Variation A.

**Fig. 93.** Design 2, Variation C, "KEY W.T. 8 AMP No. 2 Mk III," in all-bakelite molding. Note that the bakelite lever is similar to variation B.

### Key and Plug Assemblies

The KEY W.T. 8 AMP was normally fitted in an instrument or mounted on a metal or paxolin (phenolic) baseplate, providing a stable fixture. When used under field conditions, a cover was provided, protecting the operator from high voltage and the key from dust and rough handling. The key and cover, complete with lead and jack plug, was designated a KEY AND PLUG ASSEMBLY. A variety of KEY W.T. 8 AMP NO. 2 models can be found mounted in the British assemblies. The Canadian- and US-made assemblies, however, had an exclusive key for every variation. Canvas knee straps are provided on the later KEY AND PLUG ASSEMBLIES.

**Fig. 94.** "KEY AND PLUG ASSEMBLY NO. 2B" (ZA 4500) was used with Wireless Sets Nos. 11, 12, 22, 33 and 53. It consisted of a metal base-plate on which a KEY W.T. 8 AMP (here shown with design 2, version A) was mounted. It had a large round knob guard and a twin connecting cord ending in a tip-and-sleeve plug. The initial No. 2 assembly was used with Wireless Set No. 2, while No. 2C was used with WS No. 11 in tanks. The No. 2D version could be found in Wireless Remote Control Unit G. For mounting on a table the base-plate could be fixed on "Slide No. 1."

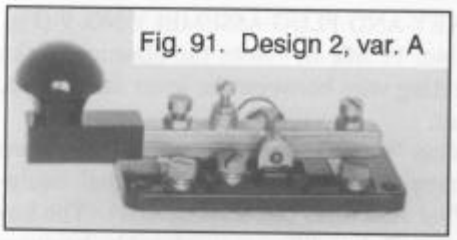


Fig. 91. Design 2, var. A

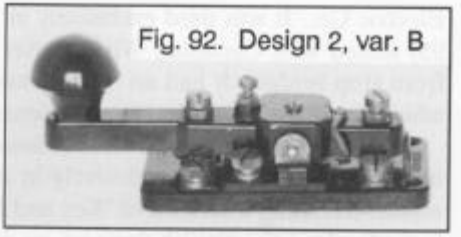


Fig. 92. Design 2, var. B

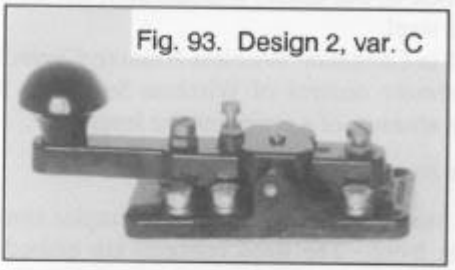


Fig. 93. Design 2, var. C

Fig. 94. "KEY AND PLUG ASSEMBLY NO. 2B "

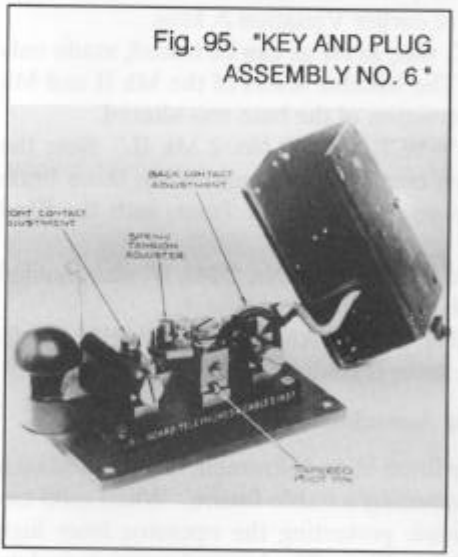


Fig. 95. "KEY AND PLUG ASSEMBLY NO. 6 "

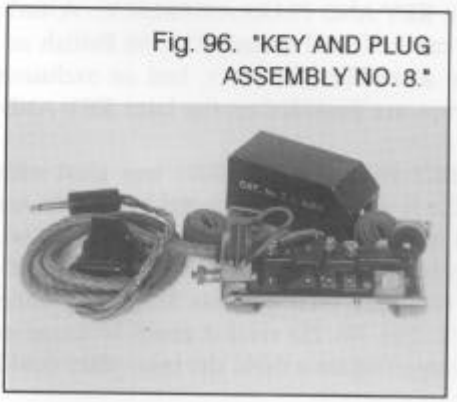


Fig. 96. "KEY AND PLUG ASSEMBLY NO. 8."

Fig. 97. Wireless Set No. 18

**Fig. 95.** "KEY AND PLUG ASSEMBLY No. 6" was used with Wireless Set No. 9. The key in the picture is a Design 1, variation B, on a paxolin base. The metal cover slides backward over the key. Note a different style of lever-protection cover having an additional guard.

**Fig. 96.** "KEY AND PLUG ASSEMBLY NO. 8" (ZA 4354), shown with design 2, version C key, was used with Wireless Sets Nos. 18 and 68. A send-receive switch is embodied in the assembly on the front below the key knob. A pin, fixed through a hole drilled in the base of the key, disables the key during receive. An aerial connector plug is normally stowed in a round spacing at the rear of the key. The assembly has a multi-wire cord ending in a two-point key plug and four-point connector to the transmit-receive circuit. A tropical version of the assembly is known as Key and Plug Assembly No. 8B (ZA 24790). This assembly can be recognized easily by its cover/metal baseplate of olive-drab color, a plug filled with moisture-resisting compound, and a rubber-covered cord. It was used with tropicalized versions of the No. 18 and 68 sets.

**Fig. 97.** Wireless Set No. 18. Developed in 1940, this was the standard British Army man-pack radio during WW II. It operated between 6 and 9 MHz with a range of 6 to 10 miles. The set was self-contained and comprised separate receiver (upper unit), transmitter (lower unit) and battery pack (in the bottom of the set). When operating CW, the transmit-receive switch (controlling the tube filaments of transmitter and receiver only) was part of the Key and Plug Assembly No. 8.

**Fig. 98.** "KEY AND PLUG ASSEMBLY NO. 9" (ZA 0937) was developed primarily for British Wireless Set No. 19 but later issued with other radios. The assembly shown in the picture has a design 2, version A key. Note the cardboard protection disk over the jack plug protecting the operator against contacting the high voltage when plugging into the set. (Canadian and some US-made sets had a cunningly devised protection flange mounted over the key socket.) Principally, No. 9 Key and Plug Assemblies were interchangeable. Careful study of wartime photographs shows a mixture in their use. Other British (tropicalized) No. 9 Assemblies are recorded, e. g., No. 9A (ZA 17693) and No. 9 Mk I/I (ZA 26291), differing very little from the initial No. 9.

**Fig. 99.** Early "KEY AND PLUG ASSEMBLY NO. 9," having a J-38 Morse key made in the US for Wireless Set No. 19 Mk II. The assembly has a very flat shape of the metal cover and uses an American PL-55 plug. Significant is the British mushroom-style knob and knob guard. A rubber sleeve over the key lever acts a protection cover. Compare this model with a standard J-38 and note the modification for reducing the size by having the hand-set lever screws replaced by the locking nuts inside.

**Fig. 100.** "KEY AND PLUG ASSEMBLY NO. 9" manufactured by Bunnell, issued with US-made Wireless Set No. 19 Mk II, uses exclusively the Design 1, Variation F key. The assembly name is printed on the side of the lever-protection cover. The metal protection cover has a black sprinkle finish; the connection cord is black, having a PL-55 plug.

**Fig. 101.** Northern Electric Co. "KEY AND PLUG ASSEMBLY R11950" was used with Canadian Wireless Set No. 19 Mk II and Mk III. (R11950 was the manufacturer's reference number; the unit was normally issued as "Key and Plug Assembly No. 9.") It has a Design 1, variation E key. The assembly name is

Fig. 98. "KEY AND PLUG ASSEMBLY NO. 9 "

Fig. 99. "KEY AND PLUG ASSEMBLY NO. 9" (early US-made)

Fig. 100. "KEY AND PLUG ASSEMBLY NO. 9" (Bunnell).

Fig. 101. "KEY AND PLUG ASSEMBLY R11950 "

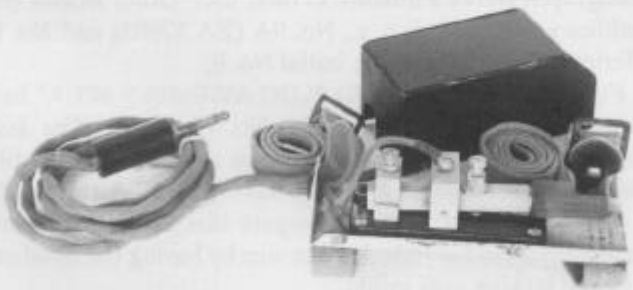
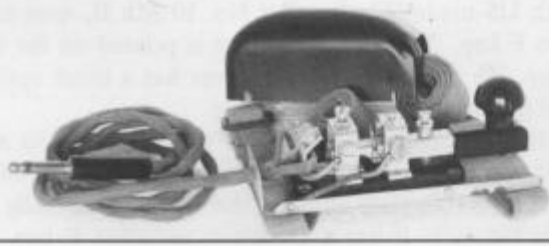


Fig. 102. "KEY AND PLUG ASSEMBLY NO. 9 CDN WESTCLOX "



pressed into the front of the baseplate.

**Fig. 102.** Canadian "KEY AND PLUG ASSEMBLY NO. 9 CDN WESTCLOX" had a Design 1, Variation F key, made by Westclox. Note the round shape of the metal protection cover and PL-55 plug. The assembly name is pressed into the metal base plate. It was used primarily with Canadian Wireless Sets No. 19 Mk III and No. 52.

**Fig. 103.** Wireless Set No. 19 Mk III (Can). Developed for armored-vehicle communication early in WW II, the set was also used in other roles (here shown as a ground station mounted on a wooden base). The set consisted basically of a control unit (left), variometer for tuning the aerial (cylinder above control unit), power unit (center) and transmitter-receiver (right). It comprised three main functional units: the "A" set, operating from 2-8 MHz on radiotelephone, MCW or CW, and providing a range of about 10 miles; the "B" set, operating on 235 MHz with a very limited range; and an intercom set for crew communication. The Key and Plug Assembly No. 9 was made primarily for this set.

**Fig. 104.** Wireless Set No. 29 (Can), in ground-station configuration. The picture includes "KEY AND PLUG ASSEMBLY CDN NO. 9/2T" (ZA/Can 232). The assembly is very similar to the earlier Canadian Westclox No. 9 assembly, having a tropical finish.

**Fig. 105.** "KEY AND PLUG ASSEMBLY NO. 19" (ZA 28656). This unit was used with Wireless Sets Nos. 62 and C12. The assembly is provided with a "snatch" plug for inserting into one of the drop leads on the set. A snatch socket at the back of the assembly accommodates a second microphone and receiver headgear assembly in addition to the key. The key assembly is also known under "Key and Plug, Telegraph," NATO Stock No. Z1/5805-99-420-5943.

**Fig. 106.** Wireless Set No. 62, showing the connection of the KEY AND PLUG ASSEMBLY NO. 19. The No. 62 set was developed in 1944 and saw operational use at the end of WW II. The frequency range covered 1.6 to 10 MHz. It was built as a self-contained unit powered by a 12-volt battery. The set remained in use up to the 1960s.

## 100+ KEYS IN A BARN

Years ago, during a holiday vacation roaming around in Flanders, Belgium, in search of a town named Meulestede (obviously the place of one of the author's ancestors), we passed a war-surplus store (named "Stock Americain"). Stopping and making inquiries, it appeared that the owner had ceased trading. However, he invited me to have a look in his former storage barn on the other side of the road. Beside a load of rusty junk, I spotted a number of dusty crates filled with rusty Morse keys, apparently stored there a long time. A modest sum made me owner of the lot, not knowing that this included a nest of field-mice, hidden in the bottom of one of the crates. On return home, I dumped the crates in the garage and forgot the whole thing until the very next week my wife complained about mice . . . Eventually I got rid of the creatures and repacked the keys into cartons "for future use."

During preparation of this story, my wife reminded me of the tale. Opening the cartons after 16-odd years, they revealed a treasure of about 120 mainly British "KEY W.T. 8 AMP No. 2" Morse keys and "KEY AND PLUG ASSEMBLIES"

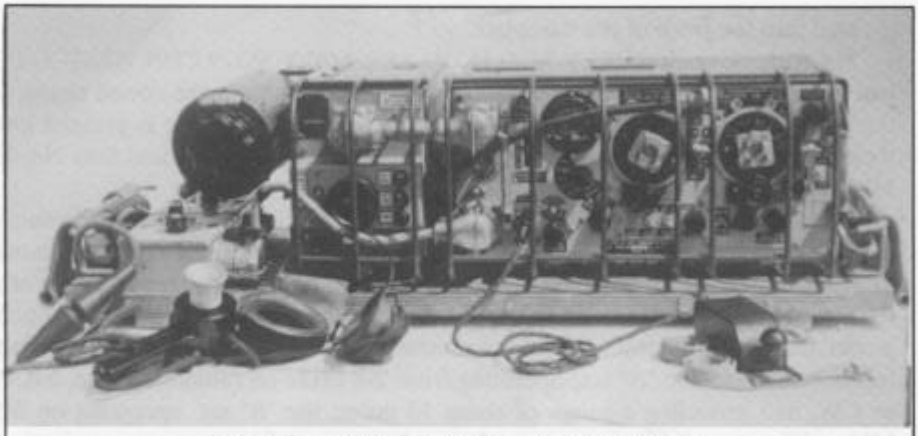


Fig. 103. Wireless Set No. 19 Mk III (Can)

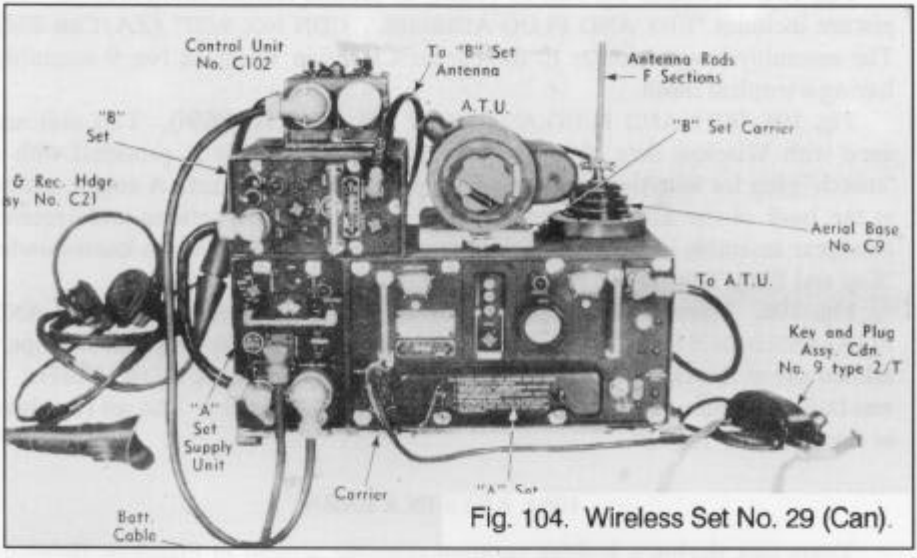



Fig. 104. Wireless Set No. 29 (Can).

Fig. 105. "KEY AND PLUG ASSEMBLY NO. 19"

in every design and variation. Some of the better specimens are pictured above. Fig. 107 illustrates the condition of some of the keys as obtained.

**Fig. 107.** Typical key and plug assemblies found by the author in Belgium. After long storage, fungus has grown all over the assembly. After cleaning it is remarkable to see how well the keys survived.

## FINALLY

Incorporated in this paper are abstracts from various articles by the author, in which more detailed information about a particular subject can be found.

Many of the instruments or systems, e. g., the German "Sutel," Power Buzzer, and Eureka-Rebecca, are subjects for more detailed publication in future issues of the *Old Timer's Bulletin*.

## ACKNOWLEDGEMENTS

Thanks are due to John Taylor, G0AKN, for making final corrections to the manuscript; also to R. Staritz, Bamberg, Germany; A. O. Bauer, Diemen, Holland; J. P. Bodifee, Deventer, Holland; J. Rijnders, Langelo, Holland; B. Warner, Ashford, England; and L. A. Sibley, Flemington, NJ, USA, for providing additional information and permission to take photographs from their collections.

This paper could not have been produced without the help of my father, Anton Meulstee, who made most of the photographs, including difficult reproductions from technical manuals with the usual poor-quality pictures.

The author is indebted to Dr. P. Thwaites, deputy director; Major R. Pickard, curator; and the staff of the Royal Signals Museum, Blandford Camp, Dorset, UK, for their help and permission to publish various drawings and photographs from the museum historical library. A selection was made for this paper from the large number of Morse keys on permanent display on the museum.

Special thanks go to Murray D. Willer, VE3FRX, who made the author interested in the fascinating world of Morse keys.

## SOURCES OF KEYS/PHOTOGRAPHS

Royal Signals Museum collection: Figs. 3, 6, 8, 12, 14, 15, 23, 28, 30-32, 34, 41, 42, 44, 47, 48, 76-78, 80, 81.
A. O. Bauer: Figs. 51, 53.
J. Bodifee ("Signals Collection"): Figs. 43, 55, 58, 65, 79, 82.
J. Rijnders: Figs. 66-75.
L. A. Sibley: Figs. 20, 59.
R. Staritz: Figs. 5, 7, 16.
B. Warner ("2LO") collection: Figs. 11, 17, 26, 60, 62, 63.

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2. L. R. Moreau and M. D. Willer, "Foreign and Military Telegraph Keys," AWA Review, Vol. 3 (Holcomb, NY: Antique Wireless Association, 1988), pp. 98-119.

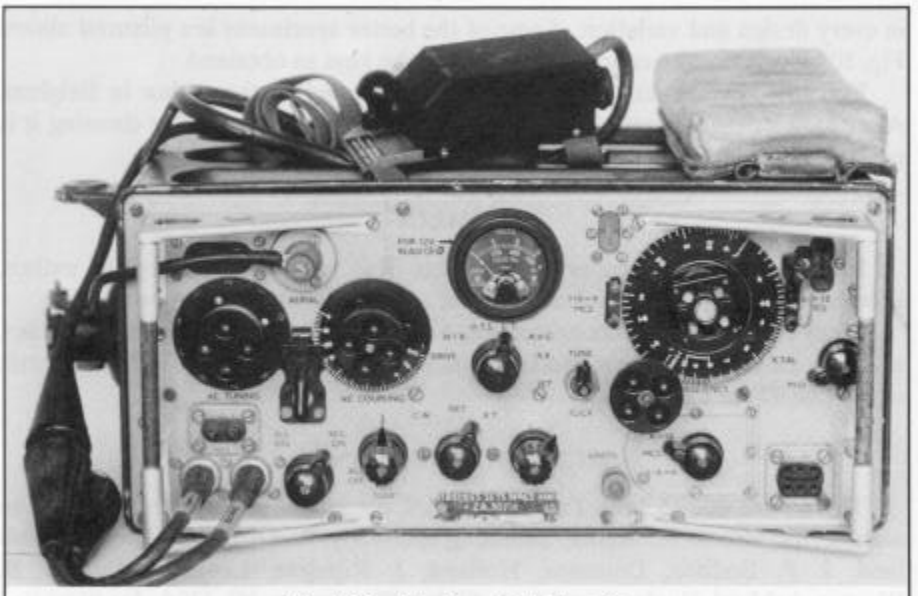

Fig. 106. Wireless Set No. 62

Fig. 107. Key-and-plug assemblies "as found "

3. L. Meulstee, "Earth Current Signalling, the History of the Power Buzzer," *Journal Royal Signals Institution*, Vol. XVIII, No. 4, Spring 1988, pp. 228-235.
4. L. Meulstee, "Fullerphone," *Old Timer's Bulletin*, Vol. 30, No. 3, Nov. 1989, pp. 16-18.
5. L. Meulstee, "Saved by Radio: Evolution in Air-Sea Rescue Transmitters," *Radio Bygones*, No. 9, Christmas 1990, reprinted in the *Old Timer's Bulletin*, Vol. 31, No. 4, Feb. 1991, pp. 17-21.
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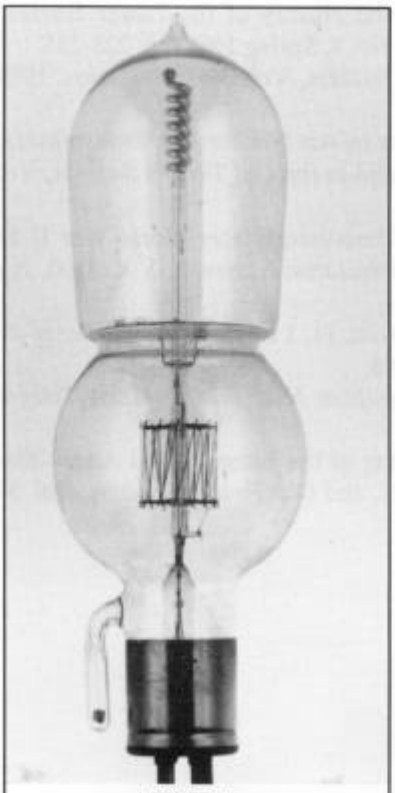
8. L. Meulstee, "The Sutel 40," *Morsum Magnificat, Magazine for Morse-Telegraphy*, No. 15, Spring 1990, pp. 1-5.
9. L. Meulstee, "Larkspur," *Q-Five*, newsletter of the International Angry-Nine Association, Vol. 2, No. 1, Feb. 1993, pp. 9-16, and *Old Timer's Bulletin*, Vol. 34, No. 4, Nov. 1993, pp. 14-19.

**Louis Meulstee, PA0PCR**

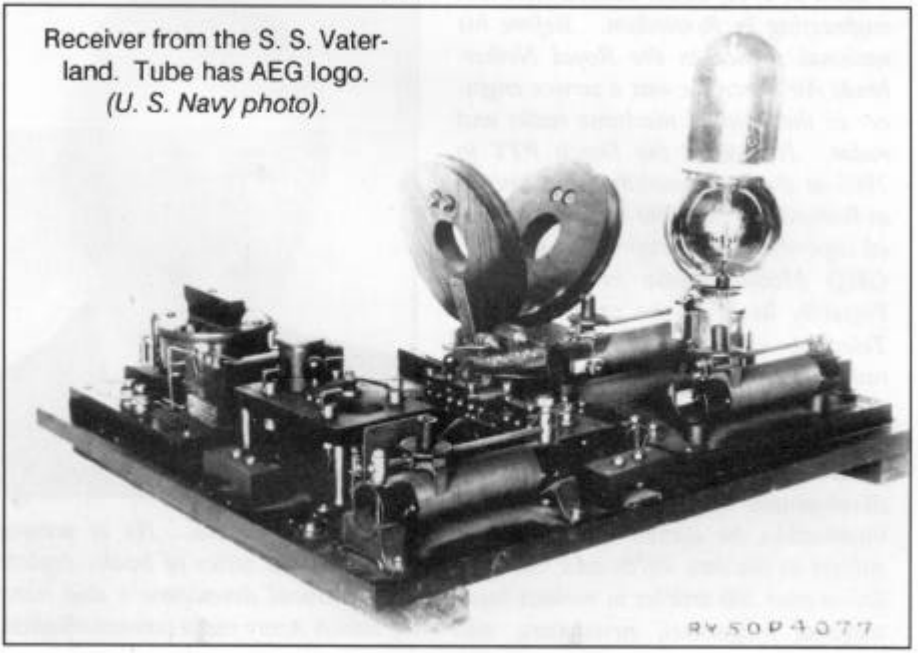
*Born in 1942, Louis studied electrical engineering in Rotterdam. Before his national service in the Royal Netherlands Air Force, he was a service engineer in the field of maritime radio and radar. He joined the Dutch PTT in 1965 at the local mobile-radio branch at Rotterdam. In 1980 he was appointed supervising field engineer at the PTT GHQ Mobile Radio in the Hague. Presently he is at the privatized PTT Telecom, engaged in major mobile-radio projects including satellite communication. Louis lives in Schiedam with his wife and two daughters.*

*Always interested in the history and development of military (radio) communication, he started writing on this subject in the late 1970s and has published over 100 articles in various international magazines, newsletters, and professional papers. He is presently working on a series of books depicting the technical development and history of British Army radio communication.*



LRS Relay
(Tyne Collection)

High-frequency amplifier from the S. S. Vaterland *(U. S. Navy photo)*



Receiver from the S. S. Vaterland. Tube has AEG logo. *(U. S. Navy photo)*.

# RARE TUBES: HOW TO RECOGNIZE THEM, AND WHY THEY ARE RARE

**Gerald F. J. Tyne**

*[Adapted from a presentation by tube historian Gerald F. J. Tyne at the AWA Conference held at Mason, Ohio, October 9, 1965. Since 1965, a number of previously unknown samples of these tubes have been discovered. Although their absolute numbers have increased, their historical importance has not diminished. Original manuscript by courtesy of Bruce Kelley. Edited for publication by J. Vanicek and L. Sibley. Photographs, unless otherwise noted, by J. Vanicek.]*

## THE LRS RELAY

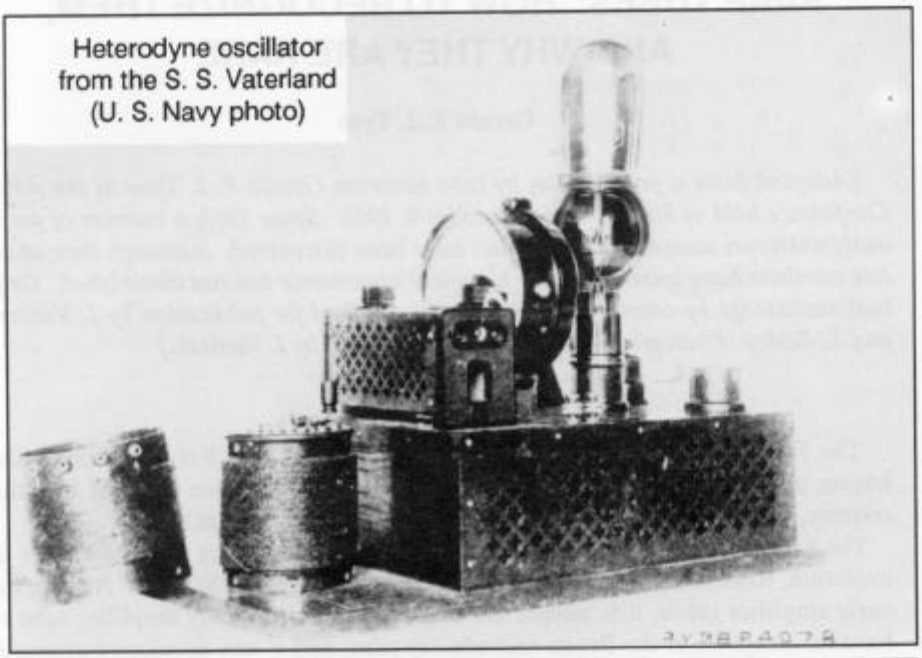
The first tube to be discussed is usually called the LRS Relay, although also known as the von Lieben tube. It is rare because few were brought into this country, and they were very expensive, about $250 each at that time.

The LRS Relay gets its name from the three men who were responsible for its evolution, Robert von Lieben, Eugen Reisz, and Siegmund Strauss. Among the early amplifier tubes, it is unique for two things: it is the only amplifier tube to have its inception in the Braun cathode-ray tube, and it was developed primarily for use as a telephone repeater. Robert von Lieben, the son of wealthy parents, was born in Vienna in 1878, and became interested in electrical engineering at an early age. He studied under Nernst at the University of GÖttingen, and in 1903, at the age of 25, set up his own physical laboratory. He became enamored with the problem of producing a "telephone relay," and with the aid of his parents purchased a telephone factory in Olmutz (Bavaria). This is where he met Eugen Reisz.

In 1905 he started trying to adapt the Braun type of cathode-ray tube for this application. By March 1906 he was far enough along to apply for a patent for such a device, which patent was published in November 1906 as D. R. P. 179807, entitled "Cathode Ray Relay."

In this patent, a Wehnelt cathode is used, shaped like a concave mirror, to focus the cathode rays on openings in two concentric cylinders which act as anodes. The focused beam passes through the holes and impinges on the inner cylinder. The patent drawing shows magnetic control of the beam, but the text states that either electrostatic or electromagnetic control can be used. It also states that the device must be "highly evacuated." The current to be amplified was passed through the coil, and altered the focus of the beam, so that more or less of it impinged on the outer cylinder, and thus varied the inner-anode current.

This device went through several modifications and intermediate patents. The concave-mirror cathode with its nonuniform emission was abandoned, and difficulty in maintaining the vacuum because of inability to outgas the metal parts resulted in the use of an ionized gas (mercury vapor). Electrostatic control, based on the work of de Forest (to which reference is made in the final patent) was used instead of magnetic control. The final patent was applied for in December 1910 and published in July 1912.



Heterodyne oscillator from the S. S. Vaterland (U. S. Navy photo)

5. Lieben Relay Tubes.

The Lieben gaseous relays, of which fourteen were found on the ship, have not been studied thoroly to date, but their important features, such as filament characteristics, filament coating material, are under investigation.

These relays seem rather inefficient, and require nearly 50 watts filament input rate. Plate voltage required varies from 300 to 500 volts, approximate values. Oscillations are readily obtained over the range which the circuit apparatus permitted, from 250 to 10,000 meters. The lower limit is probably far below 250 meters. Outputs of the order of 10 watts can be secured from one relay. Being of gaseous type, operation is accompanied by ionization of the medium, indicated by blue glow. Travelling "hot spots" of blue fire are often observed on or near the grid on the cathode side.

These relays are subject to fatigue. After about one hour of use, higher plate voltages must be used to start oscillations if for any reason they have been stopped. After about eight hours use, they will not oscillate at all, even with 525 volts on the plate, as least with the maximum inductive back coupling supplied in the apparatus. After ten hours inactivity, the fatigue completely disappears but again appears on extended use. This effect was found on all bulbs tested.

The blue glow of ionization is light when the bulb is first put into service and grows more intense as the period of use lengthens. It seems to be due to increase of gas pressure, possibly caused by the heat generated. After a period of inactivity the same conditions are repeated.

Excerpt from the U. S. Navy report on equipment from the S. S. Vaterland, RY 42A 106, of May 10, 1918.

According to published information, there were two sizes of this relay, the overall heights being 12-½ and 7-½ inches; and two types of grid construction, one a perforated aluminum disk, the other a fine gauze. Published photographs also show two types of base. Those that I have seen are marked with the insignia of AEG, although the one in the Science Museum at Kensington has Telefunken markings as well as AEG. Whether both types of grid were used in both sizes is not known.

These tubes operated at 24-30 volts on the filament, the current being about 2 amperes. The anode voltage was 220. They were unstable, their characteristics varied greatly with temperature, and they were eventually superseded by high-vacuum devices.

This is the tube, however, which was used by Alexander Meissner in his first local oscillator for heterodyne reception, in May 1913. Some were used at the Sayville station of the Atlantic Communications Company for heterodyne reception from Germany. This station was taken over by the U. S. Navy in 1915, and there may have been some spare tubes there. When the S. S. Vaterland was taken over by the U. S. in 1917 there were 14 of these tubes in her stores. Some of these may still be in a Navy storehouse somewhere.

These tubes are rare, not only in this country but in Europe. There is (or was) one in the Deutsches Museum in Munich, one in the Reichspost Museum (which had no spares), one in the Science Museum in Kensington, and one in the McVitie-Weston Collection, which was formerly in the possession of Standard Telephones and Cables but now at the Science Museum. In the U. S., there are at least two in private collections, one in the Smithsonian, and one in the museum stores of AT&T Bell Laboratories. [Since this paper was written, one was acquired by AWA and is now displayed in the Museum.] Mine was obtained from a former Expert Radio Aide of the Navy, so it probably came from the Vaterland spares. When I got it, he couldn't remember where he had obtained it.

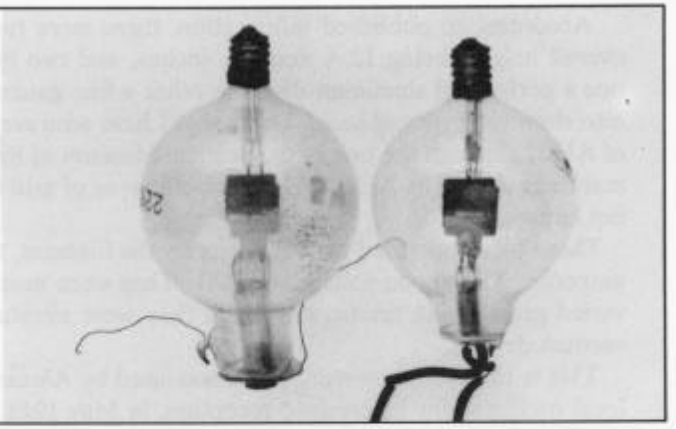
## THE MARCONI TYPE D

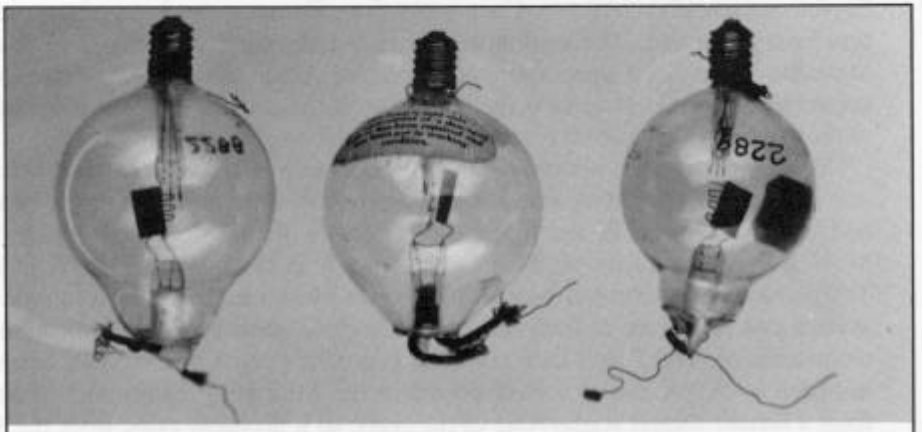
The next tube to be considered is the Marconi Type D valve. It was a triode made by the American Marconi Company in their factory at Aldene, N. J., up to October 1915. This is the valve which infringed the de Forest triode patent, and concerning which the Marconi Company confessed judgment at the beginning of the Marconi - de Forest litigation. The Type D valve was intended for use in conjunction with the Marconi Type 105 Receiver. According to the shop records of the factory, the highest serial number assigned to this valve was 656. I have Serial No. 542, and another which does not have a serial number marked on it. Number 542 has a white powder on the inside of the glass, presumably phosphorous pentoxide, to aid in maintaining the vacuum by the absorption of occluded water vapor.

All Type D valves are single-filament (tungsten) and operate at three to four volts. They are fairly close copies of the spherical audion except for two things. There are extension tabs at the top of the plates, to which the support wire is soldered, and only one support wire is used.

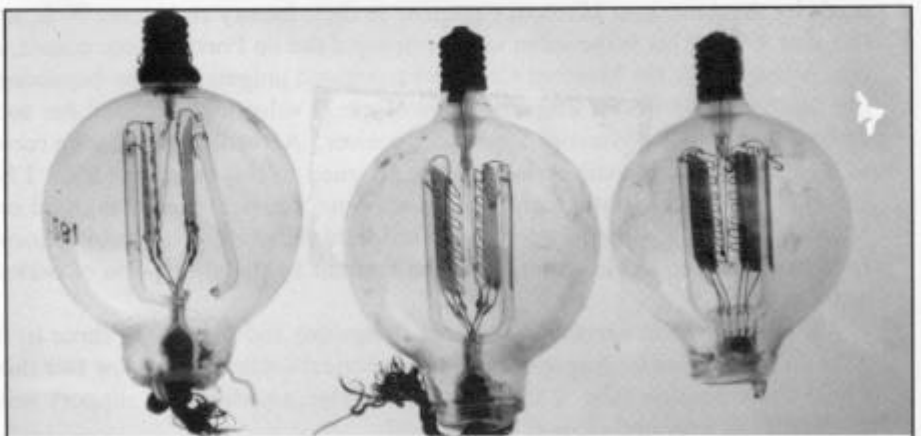
Although the Type D valve was put into production in 1913, the shop drawing was dated September 27, 1915, shortly before production was stopped. These

Marconi
Type D valves
(Tyne Collection)





Bootleg audions. Left and right: Tyne Collection. Center: originally from Kailus Collection (has black pitch in end instead of plaster). Label ingenuously declares "This lamp is sold only as a replacement of a damaged bulb or has been repaired and has been put in working condition."



Audions with glass arbors. Left: De Forest (Tyne Collection). Center: De Forest (Fetsch Collection). Right: Western Electric.

tubes are rare for two reasons: so few were made, and they were not sold but issued to the Marconi long-distance stations.

## "BOOTLEG" AUDIONS

Now let us consider the question of "bootleg" audions, by which I mean audions illegally manufactured and sold prior to World War I. This is a subject on which it is difficult to talk with any authority, since general statements based on knowledge of specific specimens could readily be negated by the discovery of previously unknown samples. Such tubes are rare, since they were the product of one individual or one small group, so that no one produced very many. In general, based on samples I have seen, they followed rather closely the general structure and element configuration of the McCandless-made audions, but were somewhat cruder. The ones I have are double-filament, but have only a single support wire for the plate. McCandless-made audions have two support wires, one to each upper corner, or two wires in the center, one straight and one bowed, to increase rigidity. The support wires were always welded to the plate. McCandless used pitch to fill the upper stem, or left it unfilled. The bootlegs I have are filled with what appears to be plaster of Paris, to form a considerable mound on top. Both of mine are single-grid and -plate tubes, and were sold in 1912. I have had other tubes described to me in which holes were drilled in the upper corners of the plate, the support wires being put through the holes and pinched flat, but have never seen such a form of construction.

## RARE AUDIONS

Probably the rarest type of de Forest triode is the candelabra-based large spherical audion made at Highbridge in 1914-15. It had a single filament with large plates and grids which were supported by glass arbors, in a manner similar to that of the first Western Electric repeater tube*. They differed from the WE tube in that the plane of the upper press is the same as that of the lower. In the WE tube the presses are at right angles to each other. This necessitated a double bend in the support arbor of the audion. Note that the audion has one arbor which has broken away from the press. This sometimes occurred in the early WE tubes, since it was difficult to anneal the joint between the arbor and the press satisfactorily.

## THE ROUND VALVES

The Round valves are so called from the name of their designer, H. J. (later Captain) Round. They are rare in this country because, except for a few used by the American Marconi Co., there was no reason for their importation. In 1912

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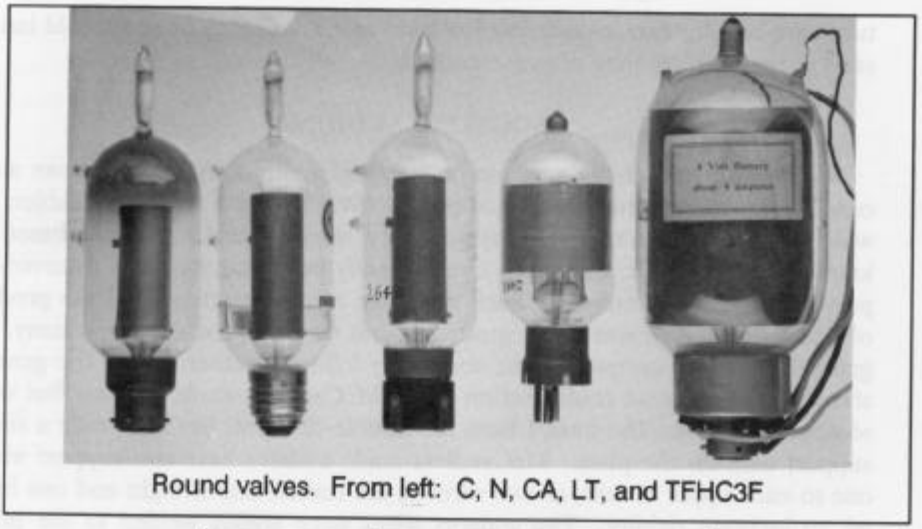
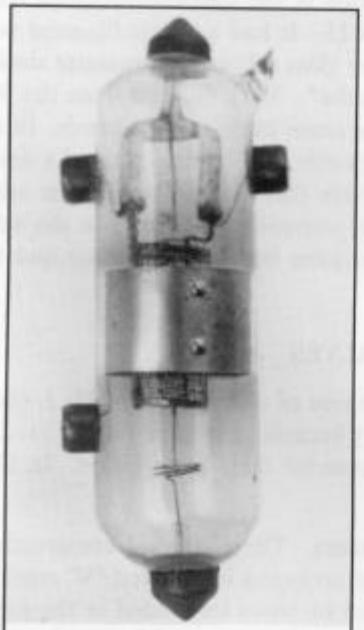
* The tubes illustrated each have two filaments. Their internal constructions are identical. In both tubes, the filaments are arranged in inverted "V" configurations. The apexes of the "V"s are supported by wires imbedded in the press. The filament ends are connected to platinum lead-out wires. The two lead-out wires, at the center of the press are connected together to form the common filament connection.

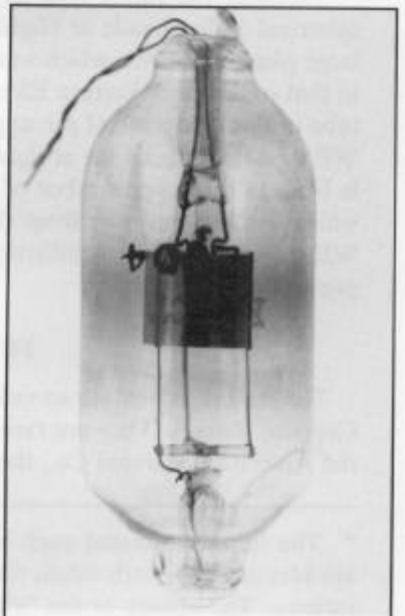


Round valves. From left: C, N, CA, LT, and TFHC3F

Round LT
(top view)



FE1 ("Four Element 1"?).



ERECT ("E rectifier"?) diode

Round was at the Glace Bay station of the British Marconi Co., and realized that it would be well nigh impossible to erect an antenna large enough to trap the energy necessary to insure reliable transatlantic communication. Having had some slight experience with two de Forest audions which Marconi had obtained from the Italian Navy, to which they had been submitted by de Forest, he decided that such a device might be used to amplify the antenna output before rectification was attempted. On the spot he designed a tube with a cylindrical grid and plate, and took the design back to England where he had four tubes made by Edison & Swan Co., using carbon filaments.

He received the tubes just about the time C. S. Franklin came back from Germany with information on the work done by Alexander Meissner using the von Lieben tube. Using Meissner's circuit and one of his tubes, he built an HF amplifier which worked satisfactorily and later made an oscillator as well. Round felt that it was essential that the grid completely surround the filament, hence his tubes used a grid of wire gauze to accomplish this. He also felt that the valves should be of large size to minimize the effect of changes in electrode temperatures on the gas content.

Round's valves are characterized by coated cathodes, completely enclosing grids, large cylindrical anodes in contact with the glass envelope, a large ratio of anode-filament to grid-filament distance, and long tubulations containing asbestos. Some used multiple filaments.

Round worked his valves with positive grid, hence the input impedance was low. Some of them could be kept operating, once started, without a filament battery, the filament being kept hot by positive-ion bombardment.

There were numerous different types of Round valve, designated as Types "C," "N," "T," "CA," "TF," "TN," and "LT." Most of the earlier types were equipped with bayonet bases, but the Type N, at least, was also made with a screw base. The Type N was used in the Marconi Type 27 receiver, as an RF amplifier ahead of balanced carborundum detectors. The Type N had a single filament taking three to four amperes at two to 2.5 volts, and operated with 40 volts on the anode. The Type CA was a variant of the N, somewhat smaller in size**, had an extremely fine mesh grid and a 2.5-ampere filament, and took 200 volts maximum on the anode. The Type C was a receiving tube about whose characteristics little is known. The Type T was a coarse-grid transmitting tube with multiple filaments. The TN was a variant of the T with a finer mesh grid. The TF was another variant of the T, also with multiple filaments. The Type LT was a much smaller tube fitted with a prong base. The typical Round construction can be seen in the top view. I have no information as to its use.

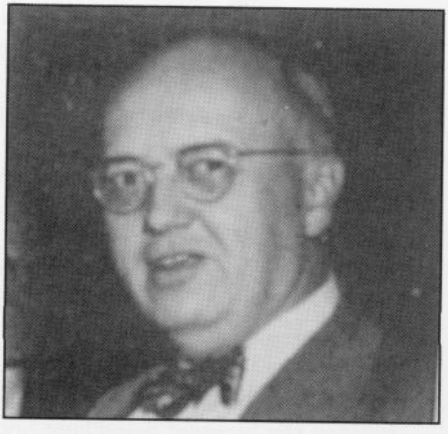
Round was responsible for the design of two other valves, both of which are extremely rare. The first is the FE-1, issued in 1919, which was the first tetrode used by the British Marconi Co., who incidentally called it a "Quadrode." I have seen only one specimen of this tube, which [was] owned by Howard Schrader, and know of only one other, which is in the McVitie-Weston Collection. Schrader got his in a horse trade with the Signal Corps Museum at Fort Monmouth.

The other is the "ERECT" diode. Round used very high voltages on some of

** The types "C" and "Ca" illustrated do not appear to support this statement.

his transmitting tubes, and is reputed to have used a Marconi 10" spark coil as a source. He needed a rectifier for these voltages, and designed the "ERECT" diode for this purpose. The American Marconi Company obtained some for test in 1920. Some of these tubes were sent to GE for examination, and Howard Schrader talked W. C. White out of them. Except for these, I know of only one other, that in the McVitie-Weston Collection.

### Gerald F. J. Tyne



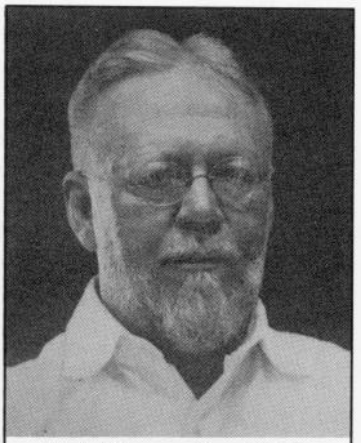
*Gerald Tyne is the individual who established vacuum-tube history in North America. A 1921 graduate of Rensselaer Polytechnic Institute, he taught there before a 1929-65 career at Bell Telephone Laboratories. With continuing research based on an early and major collection of tubes, he prepared the Saga of the Vacuum Tube, first as a series of 23 articles in "Radio News" in 1943-46, then fully developed as a 1977 book. The latter remains the premier history of pre-1930 tube development. Until his death in 1981, Tyne was a major contributor to the AWA publications and events.*

# A NEW BIBLIOGRAPHY OF REGINALD A. FESSENDEN

**David W. Kraeuter**
Washington, PA

*Most of us know of Reginald Fessenden in the abstract, as a wireless inventor, holder of a large portfolio of patents, and principal in the National Electric Signaling Company. David Kraeuter's bibliography provides a new dimension: a look at Fessenden's massive and varied writings, and at the large volume of literature that has been written about him. Ed.*

This bibliography consists of two parts. Part I is the bibliography which appeared in Helen Fessenden's book, Fessenden: Builder of Tomorrows (New York: Coward-McCann, Inc., 1940), pages 353-362. For the reader's convenience, it is reprinted here by permission of Putnam Publishing Group. Part II consists of all other items. It supplements and updates Part I.



R. A. Fessenden, 1866-1932, holder of 229 U. S. patents, 1921 winner of the IRE Medal of Honor.

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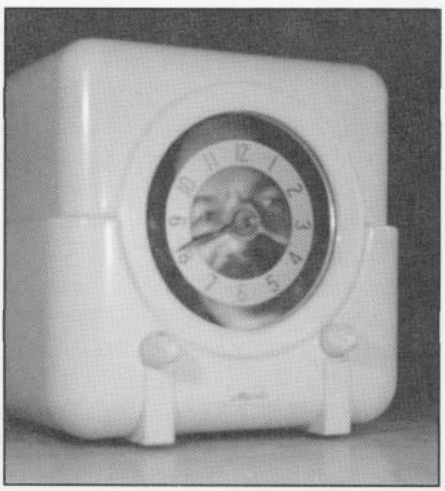
**David W. Kraeuter**



*David W. Kraeuter, shown here with a 1939 Majestic 5T, was born in Pittsburgh in 1941. He has been tinkering with electronic equipment since grade school. In 1986 he became a founding member of the Pittsburgh Antique Radio Society and has edited its journal, "The Pittsburgh Oscillator," ever since. Last year Scarecrow Press published his Radio and Television Pioneers: A Patent Bibliography, and this year a companion volume, British Radio and Television Pioneers was published. He is now editing, with Richard Brewster of PARS, a collection of historical essays and other items about pioneer radio station KDKA, and seeks suggestions from readers for items to include in this collection.*

# "FEDERAL" AS A TELEPHONE COMPANY

**Ludwell Sibley**
Flemington, New Jersey

The electronics-history community is familiar with the Federal Telephone & Telegraph Co.* of Buffalo as a radio manufacturer. Much less is known about Federal as an operating company - the "other half" of the history of this firm.

## BACKGROUND

From the expiration of the initial Bell telephone patents in 1893-94 to about 1914, the telephone industry in the U. S. was a battleground between local companies representing the Bell System, on one hand, and some 14,000 independent or "opposition" operations. The wholly owned subsidiaries and local licensees of American Bell (renamed American Telephone and Telegraph in 1900) held franchises in most of the metropolitan areas of the East, but in the rest of the country there were often two telephone companies serving the cities. Exclusive territorial franchises were usual only in the rural districts. The overlapping companies rarely interconnected; city dwellers had to subscribe to both Bell and Independent service in order to call everyone in the area.

Symbols of the opponents: the 1908 "Blue Bell," vs. the red-white-and-blue Independent shield.

Neither side had a commanding advantage in technical terms. A few Independents offered dial service using the then-new Strowger step-by-step switching system, a technology that was not really reliable or practical until the Twenties, and was clumsy to use in metro areas in any case. The other Independents and Bell restricted themselves to manual "number please" service. In the long-distance area, AT&T's ownership of the Pupin loading-coil patent meant that it could build intercity trunk facilities using 0.104" copper open wire with loading, whereas a competing company had to use 0.165" wire without loading to get a similar quality of transmission. This meant that Bell had to use only 40% as much expensive copper as the Independent.

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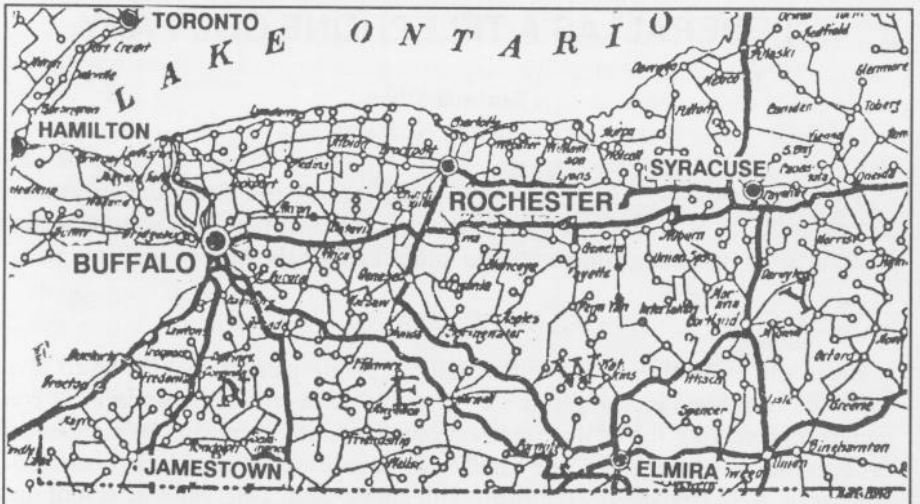
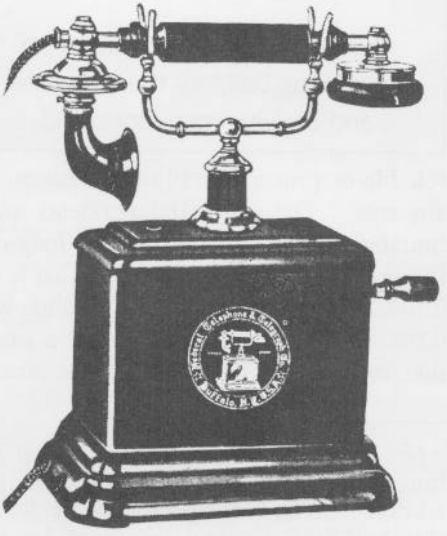
* Not to be confused with the Federal *Telegraph* Co. in California, another combined manufacturer and operating company. It built arc transmitters and provided domestic and transpacific radiotelegraph service in the Teens. Under ownership by IT&T, Federal Telegraph became Federal *Telephone and Radio*, U. S. manufacturer of the European-designed "rotary" switching system that was used, beginning in 1948, to convert the telephone system in Rochester, NY to dial operation. It survived as ITT Federal until the '60s. Federal Tel. & Tel. was also distinct from the Federal *Telephone* Co., a New Jersey holding company formed in 1899 to consolidate several telephone companies in the Midwest, and the Federal *Electric* Co., a maker of lamp sockets and the like ca. 1911.




Bell System wire routes in western New York, 1909. Heavy lines denote AT&T Long Lines Dept. facilities; light lines are New York Telephone Co. and Independent "connections." All these routes would have been open wire. They were "thin" by today's standards: as of 1904 only five trunks were needed for the important Bell traffic between Buffalo and Rochester. Not shown: facilities of competitors like the Inter-Ocean Tel. & Tel. Co.

Century No. 85 coil-in-base telephone, Frontier Tel. Co. standard equipment in 1906



Federal No. 500 metal magneto telephone, ca. 1918 - source of the case design for the Junior crystal set and matching two-stage amplifier

Having the patent also meant that AT&T could use loaded cables for long-distance service (e. g., Boston-Washington). Without loading, cable was useless to the Independents beyond 10 miles or so.

This was a time when 1890s populism was still alive, and Eastern capitalists like Bell were viewed with suspicion in the rest of the country. That, plus local boosterism and Bell reluctance to build in unprofitable rural territory, nourished the Independent movement. The pre-1915 industry trade press was filled with fiery anti-Bell diatribes. An example:

> "[T]he Bell, despite the many severe lessons taught it by the Independents, is the same greedy, domineering, arrogant corporation it was in the palmy days of its monopoly wherever it has undisputed control . . . the people are determined to have justice in telephone service and rates and realize that they must depend on Independent companies to secure it." [1].

In the era before public-utility rate regulation developed, the Bell and Independent companies struggled, using patent litigation, rate-cutting, clandestine stock purchases through agents, and local political chicanery. The Bell interests, having access to the Eastern capital market, generally had financial stability and could thus survive rate wars. They also enjoyed the benefits of long operating experience, a central staff, uniform operating methods, better trained personnel, a large patent portfolio, etc.

Competing telephone systems were far more common than most of us realize. Some larger cities where they fought it out were:

| | | |
|---|---|---|
| Atlanta | Los Angeles | San Diego |
| Chicago | Louisville | St. Louis |
| Cleveland | Memphis | San Antonio |
| Columbus | Minneapolis | San Francisco |
| Dallas | Mobile | Seattle |
| Detroit | Nashville | Syracuse |
| Indianapolis | Oakland | Toledo |
| Jacksonville | Portland (OR) | |
| Kansas City | Richmond | |

The battle was mostly over, with Bell victorious, by the early '20s, but the Keystone Telephone Co. held out in Philadelphia until 1943. Rochester and Tampa are the only important cases where the Independent was the surviving company. That brings us to Buffalo, home of Federal.

## FEDERAL: FRONTIER, CENTURY, AND INTER-OCEAN

Federal arose from a 1908 merger of the Century Telephone Construction Co., the Frontier Telephone Co., and the Inter-Ocean Telephone & Telegraph Co.

Century had been organized in Cleveland by Burt G. Hubbell in 1899, and moved to Buffalo in 1902. As of 1906, it was competing vigorously with the other telephone makers, running full-page magazine ads cheek-to-jowl with Automatic Electric, Dean, Kellogg, Monarch, North Electric, and Stromberg-Carlson. Century claimed that their equipment was "the result of many years' practical exchange operation. We have constructed and operated a large number of exchanges . . ." Their address was 332 Ellicott St., a different site from Federal's

later factory. Century seems to have been a large but regional supplier. Reportly, their switchboards (mainly of the magneto type) had recently been shipped to the following New York and Pennsylvania villages [3]:

| | | |
|---|---|---|
| Akron | Freeville | Rush |
| Attica | Fulton | Russell, PA |
| Bath | Geneseo | Springville |
| Belmont | Hamburg | Stafford |
| Caywood | Hornell | Sugar Grove, PA |
| Charlotte | Interlaken | Truxton |
| Cortland | Ithaca | Weedsport |
| Coudersport, PA | Lancaster | Williamsville |
| Dansville | Little Valley | |
| Farmersville | Lodi | |

Presumably some of these, besides Hornell and Williamsville (see below), were towns where the operating company was affiliated with Century.** President Hubbell bought the Williams-Abbott Electric Co. of Cleveland in 1907 [4], moved it, and merged it into Century; likewise with the Corwin Electric Co. of Lafayette, Indiana in 1920 [5]. Despite the 1908 merger into Federal, Century used its original name at least as late as an advertisement in the Oct. 5, 1918 issue of *Telephony*. This is consistent with the "Century" test buzzers on radio receivers of WW I vintage.

Frontier had started in 1902, apparently taking over facilities built beginning in 1895 by the Buffalo Electrical Transit Co., and soon became one of the largest Independents. A Bell internal memo of 1904 [2] reports that

> The Frontier Telephone Company, which is the opposition company in Buffalo, have only one exchange and at the present time are operating 7000 telephones. Their rates are $3.00 and $4.00 per month [for residence and business service respectively - LAS]. The Bell people there think that the opposition has not done them much harm; they state that the opposition subscribers are only in the business district and that in consequence the business men still have to retain the Bell instrument.

The third component of Federal, the Inter-Ocean Tel. & Tel. Co., was an intercity long-distance company in western New York which also controlled (at least) the telephone companies in Angelica, Phelps, and Wayland.*** It seems to have had a well developed trunk network between Buffalo and smaller cities like Jamestown.

The new Federal company provided telephone service from 1908 to at least 1921. As of 1913 [6] it had absorbed the Niagara County Home Telephone Co. and expanded into the then-suburbs of Buffalo: Blaisdale, Cheektowaga, Gar-

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** Century had a Canadian subsidiary. U. S. sources do not cover its fate, but it was mentioned in Federal ads as late as 1925.

*** Corporate history is full of names which connote larger ambitions than business realities would support. Without the loading-coil and telephone repeater patents that AT&T controlled, Inter-Ocean could never have gone coast-to-coast. Its name is reminiscent of the Tonopah & Tidewater Railroad in Nevada, which failed to reach either Tonopah or tidewater.

denville, Kenmore, Lackawanna, North Tonawanda, Roland, Tonawanda, West Seneca, and Williamsville. Other New York locations nearby included Gasport, Medina, Middleport, and Warsaw. More remote franchises were in the suburbs of Rochester; Montour Falls, NY, 105 miles distant; and Sayre, PA, 135 miles away. In Buffalo, Federal's manual service was priced below that of the New York Telephone, the successor to Bell's Buffalo Telephone Co.: a Federal flat-rate residence phone still cost the 1904 rate of $3 per month, vs. $4 for Bell. A four-party residence line was $2, vs. $2.50 for Bell. (Even a $3 monthly rate was costly: in 1993 dollars it would be about $30.) The rates were raised an unspecified amount in 1914.

Alan Douglas [7] cites the date of Federal's agreement to divest its most important operating-company property (Buffalo) as March 1, 1918. The actual transfer was delayed until Aug. 1, 1921 [8]. The obvious intent was to "bet the company" on manufacture of *telephone* equipment; Federal's small role in "wireless" as of 1918 was mainly headsets and high-frequency buzzers. The sale was part of a wave of consolidations that took place in 1917-20. It came from a multi-way negotiation which also resulted in Bell leaving Rochester and Jamestown. Federal's telephone exchanges in and near Buffalo went to New York Telephone; other properties (Rochester suburbs, Wayland, and Warsaw) went to Rochester Telephone. Bell gained about 33,000 subscribers in Buffalo and lost about 36,000 in Jamestown and Rochester. Other Federal transfers, not necessarily part of the Buffalo-Rochester sale, went to the Watkins Glen & Reading Tel. Co. (Montour Falls), the Trumansburg Home Tel. Co. (Phelps), and the Chemung Tel. Co. (Sayre).

B. G. Hubbell.

After fixing on making radios and their parts during the 1921-22 "radio craze," Federal lost interest in making telephone products, despite a change of name to Federal Telephone Manufacturing Co. It cut back on appearances at industry trade shows. By 1925 its ads in *Telephony* had shrunk to quarter-page size, emphasized only telephone sets, and were updated infrequently. By contrast, the competition was using double-page spreads. There was no Federal advertisement in the 1928 *Telephony* industry directory, although the company was still listed as making phones and switchboards. The advertising budget was clearly directed toward the radio trade.

Douglas covers the financial crisis caused by the death in 1925 of Federal's investor-president Hubbell. The latter had been a long-time telephone man. His career began early: as of mid-1898, he was secretary and treasurer of the Keystone Telephone Company (of Pittsburgh, not the Keystone company of Philadelphia), a maker of telephones and builder of lines comparable to the later Century company. As a contemporary article [9] reports,

> Mr. Hubbell claims to have inaugurated the first opposition telephone system in this country, having established an independent exchange at McKeesport, near Pittsburgh, at which time the pioneer company had 60 subscribers, for which the charge was $84 per year. The city now has 900 telephones, which are furnished at a cost of from $12 to $30 per year.

The McKeesport installation was apparently *not* the first "opposition" exchange, but was early indeed. A news item in the industry press, "The McKeesport (Pa.) Telephone Company has opened its new exchange with 200 subscribers," dates from 1891 [10].

After his experience in the industry, Hubbell was elected a director of the National Independent Telephone Association in 1911. He had been part of a NITA "committee of seven" which had begun negotiations in 1912 for a block of Bell-Independent mergers. Under his direction, Federal actually owned control of the Rochester Telephone Co. for a while beginning in 1911. In 1914 he was elected president of the Independent Telephone Association of America (a group newly formed to fight AT&T), and was a director of the U. S. Independent Telephone Association after the other trade associations merged in 1915 to form USITA. Despite this strong record, he seems to have been overlooked in terms of the Independent Telephone Pioneers Hall of Fame, a program which began long after he and his company left the telephone industry.

## THE ELMIRA MYSTERY

A consequence of looking into business histories is that more questions emerge than answers. It is tantalizing to think that, since Federal Tel. & Tel. was the operating company in Montour Falls and Sayre, it may have had a connection with Federal Radio Laboratories, 15 or so miles away in Elmira. The latter made, briefly and obscurely, the "Red Jacket RDA-2" broadcast receiver with Federal (Tel. & Tel.) parts, using the electrical design of the Federal (Tel. & Tel.) 57 [12]. The time frame was 1922-23. It is easy to hypothesize, say, an exchange manager from Montour Falls, displaced by sale of his telephone company, opening a satellite or franchised manufacturing operation. It is the usual story: "more research is needed."

## PARALLELS WITH STROMBERG-CARLSON

It is of interest to view Federal in Buffalo against its competitor Stromberg-Carlson in the rival city of Rochester. S-C was owned for a time by the early Home Telephone Co. of Rochester [11], forming another manufacturing-operating combination. Both "got into radio" deeply in the early '20s, contrasting with the brief and uncertain entries of American Electric, Automatic Electric, or Kellogg. Federal and S-C both made home receivers rather than transmitting equipment as Bell's Western Electric did. Both built sets conservatively, pricing them at the upper end of the market. Federal and S-C built the then-dominant AM stations (WGR and WHAM) in their respective cities, both eventually selling them. The difference was survival: Federal was gone in advance of the Depression, whereas S-C made consumer electronics into the '60s and is still visible in the telephone industry as Siemens Stromberg-Carlson.

## ACKNOWLEDGEMENT

Lauren Peckham offered valuable insight into the Federal Radio Laboratories - Elmira problem.

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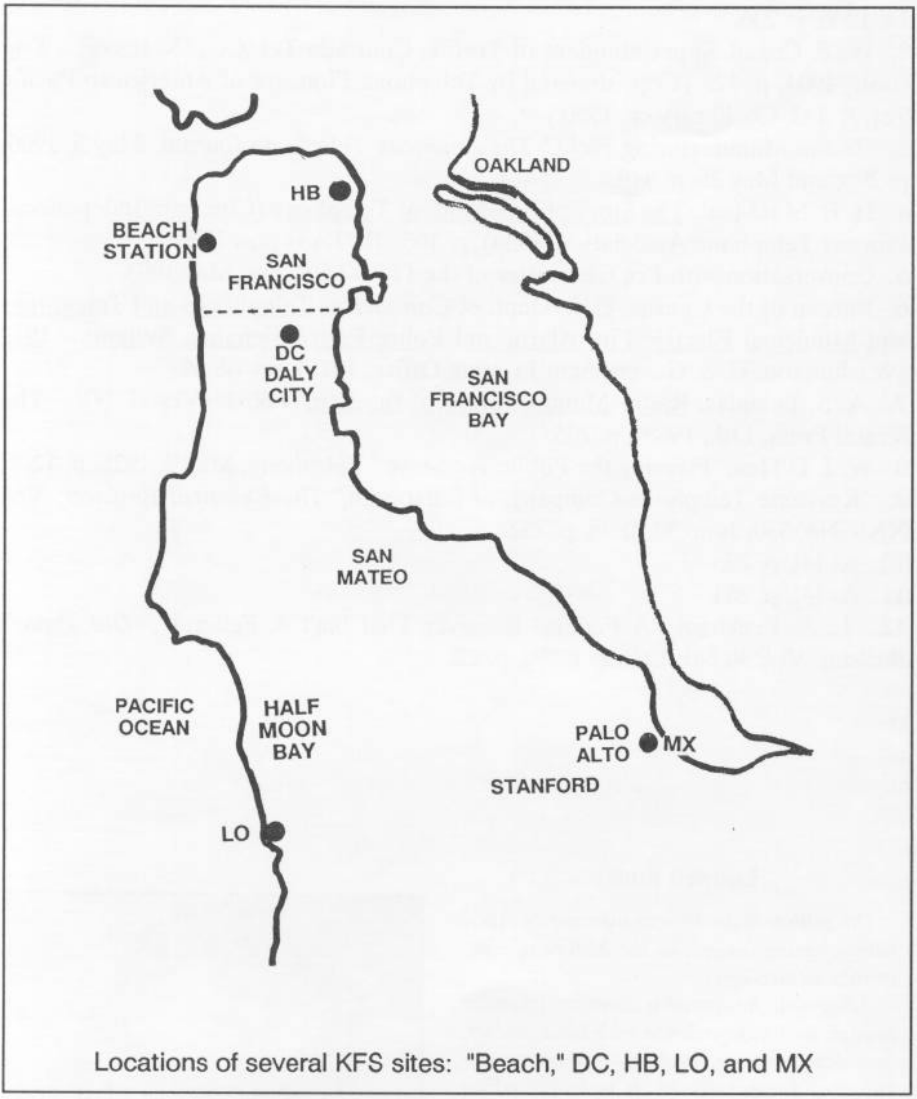
**Ludwell Sibley**

*The author is an 18-year member of AWA with a strong interest in the history of electronics technology.*

*Long-time holder of a commercial radio license, he has experience with lunar radars, broadcast systems, and military communications. He has served as technical editor of a textbook on transmission engineering and contributed to the 1993 edition of Reference Data for Engineers - Radio, Electronics, Computer, and Communications. A member of the Society of Broadcast Engineers and a senior member of the IEEE, he holds the amateur callsign KB2EVN and is a registered professional engineer.*




Locations of several KFS sites: "Beach," DC, HB, LO, and MX

# THE KFS-FEDERAL-MACKAY STORY: FROM CW ARC TO SILICON VALLEY

## THE WAVES OF PROGRESS

**Hank Olson, W6GXN and Bill Orr, W6SAI**
Menlo Park, California

This is the story of a remarkable radio station, a company, and the men who created a center of electronic communication that continues to this day.

More than that, this KFS-Federal story encapsulates the origin and growth of a spectacular area known as Silicon Valley. This "Valhalla of the mind" cannot be identified on a map, but encompasses a region of California south of San Francisco, stretching south on the Peninsula from San Carlos to San Jose, a distance of nearly 25 miles. The area is about 4 miles wide, bounded on the west by the coastal range of hills and on the east by San Francisco Bay. In this 100-square-mile strip, a pleasant climate, an outstanding university, easy access to the money market of San Francisco, and an influx of formidable thinkers combined to produce a scientific-industrial complex that changed the world.

A symbol that runs like a thread through this area and time period is Marine Radio KFS and the Federal Telegraph Company. While these entities are the stars of this story, the overall picture is much more complex. The reader is urged to seek further. Good starting points are Electronics in the West, The First 50 Years [1], and Fire in the Valley, The Making of the Personal Computer [2]. These books provide insight into the early days of radio and the ongoing technological revolution in electronic communication.

One can rarely point to a single company which spans almost the entire sweep of electronics, from the invention of the triode vacuum tube to satellite digital communications. Radio KFS is one such company [3], although it has also been known as the Poulsen Wireless Telephone and Telegraph Co., Federal Telegraph Co., Mackay Radio and Telegraph Co., and ITT Communications (with minor variations of name to enhance business dealings).

The founding entity, Poulsen Wireless Tel. and Tel. Co., began in 1909, just a few years after Lee de Forest applied for a patent on the triode vacuum tube (audion). This company continued, under its various names, until today as a communications firm using both high-frequency radio and the latest international marine satellite (INMARSAT) for ship-to-shore communication. Along the way, the company (Poulsen, Federal, Mackay, KFS) has seen or been the site of some of the most exciting mileposts in the fields of electronics and communications.

### THE VERY EARLY DAYS

The Poulsen Wireless Tel. & Tel. Co. was formed in 1909 by Cyril Elwell, a then-recent Stanford University engineering graduate, originally from Australia. He had just completed an engineering study for two San Francisco investors, the Henshaw brothers (William and Tyler), on the feasibility of a wireless telephone system invented by the late Francis Joseph McCarty. McCarty had a system using a spark-type transmitter, achieving modulation by use of a carbon micro-

phone in series with the antenna circuit. This scheme was similar to the Fessenden modulation system, except that the latter used a rotary generator, the Alexanderson alternator, as his RF source. Elwell's evaluation of the McCarty system discouraged the Henshaw brothers from further investment in wireless, but convinced Elwell that wireless telephony was practical if one had a continuous-wave generator, unlike the spark transmitters in use at the time.

## NEEDED, A SOURCE OF CONTINUOUS WAVES

The only sources of continuous waves at frequencies high enough to be considered "radio waves" were the Alexanderson alternator and the Poulsen arc. The latter was a generator using a low-voltage continuous arc in an atmosphere of hydrocarbon vapor in conjunction with a strong magnetic field.

Elwell concluded that the arc system was less expensive and more flexible in use than the alternator. In addition, the alternator was under the control of the General Electric Co., a potential competitor.

Based on these conclusions, Elwell traveled to Valdemar Poulsen's home in Denmark, secured rights to use the Poulsen generator in the U. S., and bought a 100-watt working model. He arranged for three of Poulsen's Danish assistants to come to the U. S. to set up of a 50-mile radiotelephone demonstration. With the help of the Danes (Peter V. Jensen, F. Albertus, and C. L. Schou), and using two additional high-power arcs imported from Denmark, a two-way radiotelephone test circuit was set up between Sacramento and Stockton, California.

The test was conducted on February 19, 1910 with much fanfare and publicity, with David Starr Jordan, president of Stanford, officiating. It was run, of course, to generate publicity in order to raise capital in Poulsen Wireless Tel. & Tel. Co. It garnered a large number of small stock purchases from the public.

(An interesting sidelight of the tests was that shortly afterward two of the Danes left the company to form their own firm, Magnavox, to develop the moving-coil loudspeaker, and later to form the Jensen Loudspeaker Company. These were Jensen [engineer] and Albertus [mechanic]; E. S. Pridham, another Poulsen engineer, also left to help form Magnavox.)

## THE OCEAN BEACH STATION

Less than six months after the Sacramento-Stockton tests, a wireless station was built at Ocean Beach in San Francisco, just north of the zoo at 48th Avenue and Noriega Street. This was the so-called "Beach Station," placed in operation in July 1910, and the forerunner of KFS. It had low-power radiotelephone capability and 12-kW Poulsen arcs. Until it was built, all arc transmitters had been imported from Denmark, but high cost and import duties forced Elwell's company to start making its own transmitters at a small plant at the corner of Channing and Emerson Streets in Palo Alto, California. The property was sold to the Poulsen company by Douglas Perham, who stayed on as a technician and for whom today's museum-sponsor Perham Foundation is named.

Thus, two 5-kW arcs each were built for the Sacramento and Stockton stations, and two 12-kW units for the Beach Station. (The power levels are probably not a coincidence: the two arcs imported from Denmark for the original tests were 5-kW and 12-kW.)

The Beach Station was a landmark. It used a heavy flat-top antenna suspended between two 300-foot wooden lattice masts, considerably higher than the 180-foot poles used at the Sacramento and Stockton locations. The smaller demonstration antennas apparently had capacitive "top-hats," as they were described as "umbrella types," similar to antennas used by Poulsen in Denmark.

The Beach Station was one of the first commercial stations to show that transmission and reception of radio signals could be accomplished at sea level and did not have to be done from cliffs or mountains. The station had receivers selective enough that it could tune-in either Sacramento or Stockton even if they were on the air simultaneously. Such receiving selectivity was not effective with the signals of the broad spark transmitters of the day but worked very well with the relatively "clean" CW signal of the new arc transmitters.

The primary reason for building the Beach Station was to implement one end of a San Francisco - Los Angeles point-to-point circuit. Early pictures show that the transmitter was equipped with a carbon microphone for voice transmission, suggesting that the Poulsen Wireless Tel. & Tel. Co. still had as its goal a radiotelephone circuit.

## THE POULSEN WIRELESS CORPORATION

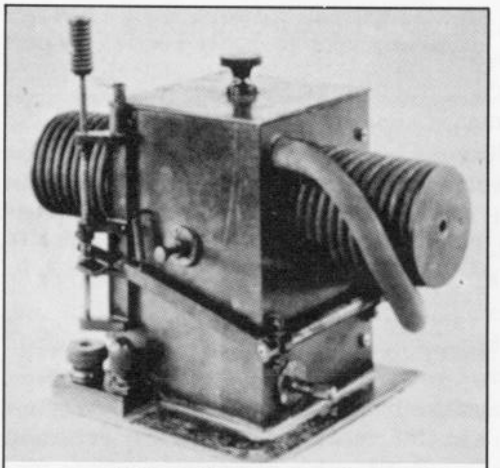
The success of the company attracted the interest of another Stanford graduate, Beach Thompson, who had been successful in establishing a new power line into San Francisco. So on January 25, 1911, the company was reorganized as the Poulsen Wireless Corporation, with Thompson as president, and a capitalization of $25 million. Thompson, with his major investors (E. W. Hopkins, George A. Pope, and J. Henry Meyer), was able to provide the much-needed capital for the proposed expansion, but in the reorganization Elwell and his Stanford associates lost control of the company to the San Francisco investors.

With the formation of the new company, the idea of radiotelephone communication seems to have been put aside, the company now concentrating on establishing a system of point-to-point telegraph services. Early in 1911, a Los Angeles station was completed and began competing with established wire telegraph services, at cut rates.

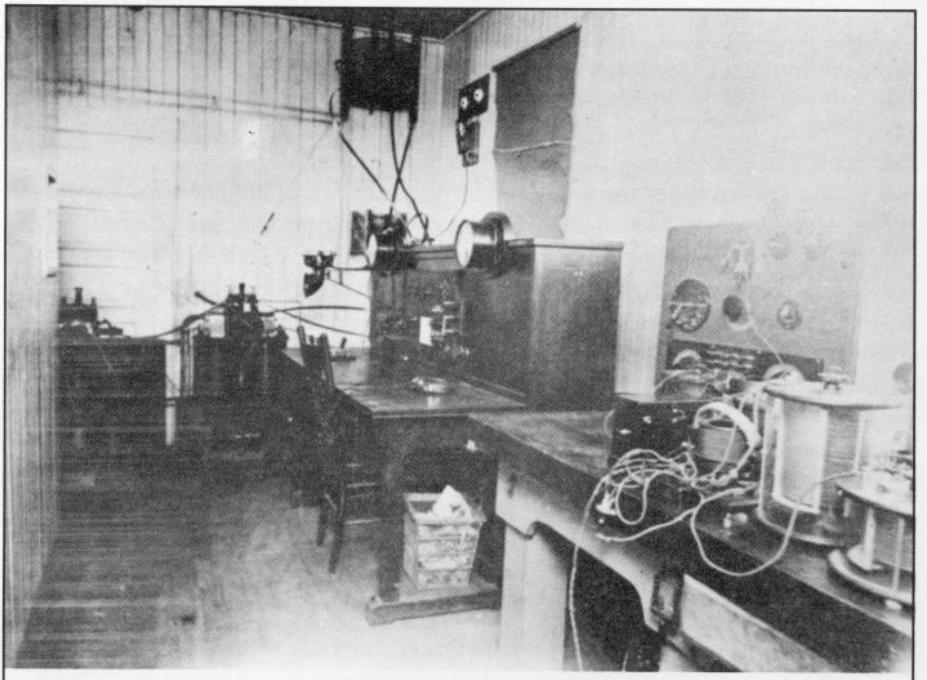
By the end of 1911 there were 18 Poulsen stations competing with overland wire services for telegraph messages. They were located in Portland and Medford (Oregon); San Diego, Los Angeles, Sacramento, Stockton, and San Francisco (California); El Paso and Fort Worth (Texas); Phoenix (Arizona); Kansas City (Missouri); and Chicago (Illinois). As this period was before the Radio Act of 1912 which led to assignment of station callsigns, apparently Poulsen Wireless Corp. simply chose its own calls, beginning with the letter "P" (Table 1).

## THE FEDERAL TELEGRAPH COMPANY

With all this activity, especially outside California, the name Federal Telegraph Co. came to be the main name by which the company did business. "Federal" was the operating company whose stock was held by Poulsen Wireless Corp. This structure was to achieve tax advantages when doing business out-of-state. As business increased, the Federal name came to be predominant and Poulsen a fading memory, although it still held the stock and the power.



100-watt arc converter
from Denmark, 1909
*Photo: as below*



"Beach station" in San Francisco, 1910, showing carbon microphone outlined above the operating desk
*Photo: Perham Foundation, via AWA Monograph No. 3*

## TABLE 1 - POULSEN ARC STATIONS BY THE END OF 1912

| Call | Location |
|---|---|
| PFW | Fort Worth, TX |
| PKC | Kansas City, MO |
| PLA | Los Angeles, CA |
| PNU | Heeia, HI |
| PNX | Phoenix, AZ |
| POL | Medford, OR (later Central Point) |
| PSC | South San Francisco, CA (early 1912) |
| PSD | San Diego, CA |
| PSF | San Francisco, CA (Beach Station) |
| PSN | Portland, OR |
| PSO | El Paso, TX |
| - | Sacramento, CA* |
| - | Stockton, CA* |

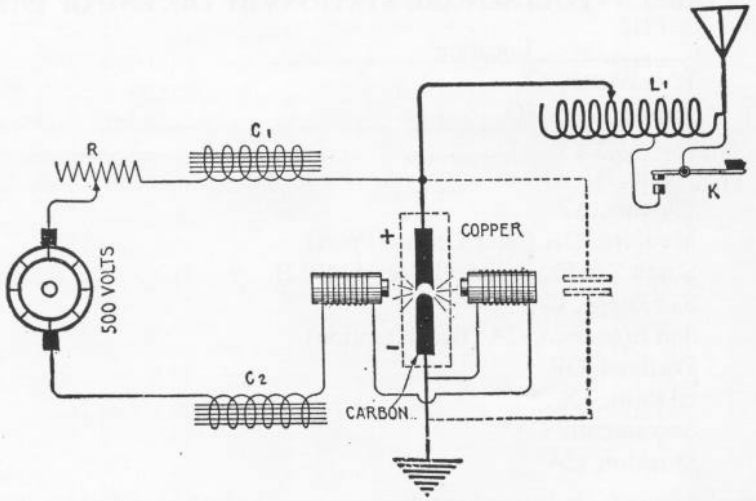
* Original stations for radiotelephone demonstrations of 1910, closed late in 1912.

## TABLE 2 - U. S. NAVAL STATIONS - FEDERAL ARC TRANSMITTERS

Data from Howeth and Dr. Fuller; source: [11]

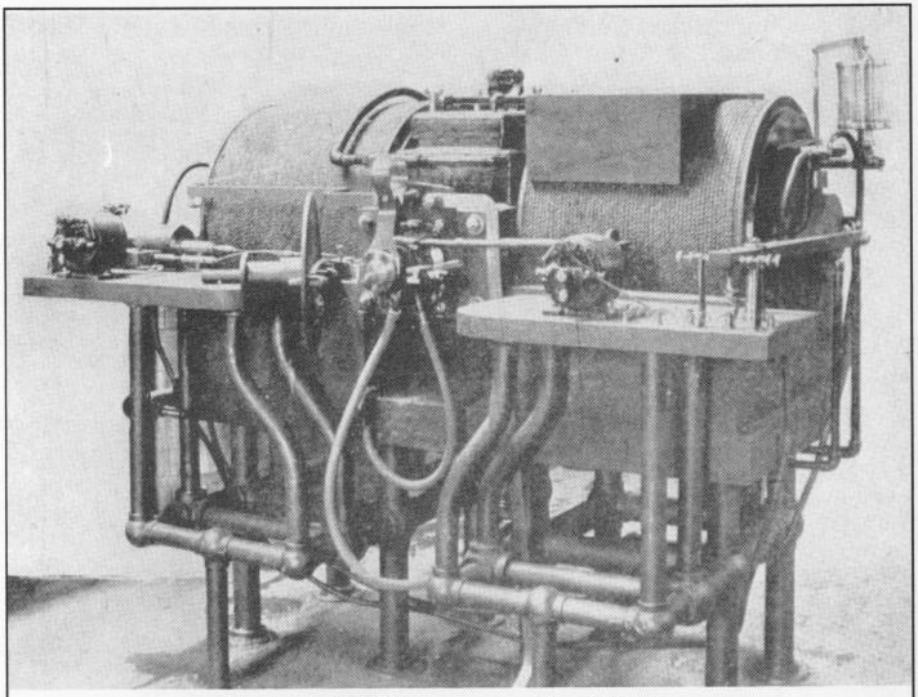
| Call | Location | kW | Completed |
|---|---|---|---|
| NAA | Arlington, VA | 30* | Dec. 1912 |
| NAD | Boston Navy Yard, MA | 30 | 1915 |
| NAJ | Great Lakes, IL | 30 | 1915 |
| NAL | Washington, DC | 30 | 1916-17 |
| NAM | Norfolk, VA | 30 | 1916-17 |
| NAO | Charleston Navy Yard, SC | 30 | 1916-17 |
| NAT | New Orleans, LA | 30 | 1916-17 |
| NAU | San Juan, PR | 30 | 1915 |
| NAW | Guantanamo, Cuba | 30 | 1915 |
| NAY | Pt. Isabella, TX | 30 | 1916-17 |
| NBA | Darien, CZ | 100 | July 1915 |
| NDD | Sayville, Long Island, NY | 200 | 1918 |
| NGL | Tampa, FL | 30 | 1916-17 |
| NPA | Cordova, AK | 30 | 1915 |
| NPC | Bremerton Navy Yard, WA | 30 | 1916-17 |
| NPG | Mare Island Navy Yard, CA | 30 | 1916-17 |
| NPL | San Diego, CA | 200 | Jan. 1917 |
| NPM | Pearl Harbor, HI | 500 | Sept. 1917 |
| NPN | Guam | 30 | 1916-17 |
| NPO | Cavite, Philippines | 500 | Dec. 1917 |
| NPQ | St. Paul Island, AK | 30 | 1916-17 |
| NPU | Tutuila, Samoa | 30 | 1916-17 |
| NSS | Annapolis, MD | 500 | 1918 |
| NVL | Seattle, WA | 30 | 1916-17 |
| NWW | Tuckerton, NJ | 30* | 1914 |
| NZR | El Cayey, PR | 200 | 1916-17 |

* 60 kW, 1916.




Basic circuit of an arc transmitter. Rheostat R regulates the DC supply current. C1 and C2 are RF chokes. L1 and the antenna capacitance determine the operating frequency. In an actual transmitter, the key K is replaced with a normally-open keying contactor. An arc converter simply consists of the arc electrodes and field coils.

*Adapted from E. E. Bucher, Practical Wireless Telegraphy, 1917*



Federal 100-kW arc converter at Darien

*Photo: A. N. Goldsmith, Radio Telephony, 1918*

## THE SAN FRANCISCO-HONOLULU CIRCUIT

Early in 1912 it was decided to go after the mainland-to-Hawaii traffic, which was inadequately served by a low-speed undersea telegraph cable (at 35 cents per word!). In order to compete on this circuit, a new station (PSC) was built at South San Francisco, equipped with a 30-kW arc transmitter and 440-foot antenna towers, and a similar station (PNU) was constructed at Heeia, Hawaii [4]. The Hawaiian station was completed in May, 1912, in an impressive 47 days, by Cyril Elwell, two San Francisco riggers, plus 25 Chinese and 25 native laborers.

The word rate for the Hawaii - San Francisco radio circuit was set at 25 cents, and 2 cents for contract press at 1500 words per day. This severely undercut the established cable tariff.

The radio circuit was a success but suffered from poor signal strength during daylight hours. To increase the signal, an additional 606-foot antenna mast was added at both South San Francisco and Hawaii. Power was boosted with new Federal 60-kW arc units.

Also in 1912, a 12-kW station was built in Chicago on the 26th floor of the Transportation Building. It used two steel masts atop the building to support its flat-top antenna [7]. Apparently this station was in service for only about a year; its "P" call sign does not appear in References 5 or 6.

## LEE DE FOREST AND HIS AUDION

While Federal was entering its expansion during early 1911, another player in the radio field, Lee de Forest, was falling on hard times. He was living on the Pacific Coast, away from investigations of an eastern grand jury into one of his earlier wireless companies. De Forest had been in San Francisco installing a wireless station on the Phelan Building and in Los Angeles constructing another on the Securities and Savings Bank Building. These stations used 500-Hz quenched-gap spark transmitters on about 2000 meters (150 kHz). Apparently because the companies in SF and LA had no facilities for collecting or delivering messages, business was not good, and finally the local sheriffs' departments padlocked the doors. Federal Telegraph was a buyer of the equipment of de Forest's defunct company at a sheriff's sale in San Francisco. De Forest was reduced to selling his personal test equipment to make ends meet.

In July, 1911 he appeared in the Palo Alto office of Federal's Cyril Elwell and sold him a Seibt wavemeter for cash. A month later de Forest came back to Federal looking for a job. Elwell and Thompson hired him with no formal contract of employment, and without a patent-release agreement, as incredible as this may seem, since de Forest was a well-known inventor with many wireless patents to his credit. This left him in the position of retaining any patent he filed for while at Federal, but also gave Federal "shop rights" by which it could use those patents without royalty.

## DEFOREST'S AUDIO AMPLIFIER

Initially, de Forest was not given a clearly defined research responsibility. He helped relocate the Medford station to Central Point nearby. However, in 1912, Federal decided to devote research time and money to develop an amplifier to be used with the Telegraphone, another Poulsen invention used to record high-

speed telegraph signals and play them back at a lower speed. The device was a primitive wire recorder.

However, when the high-speed recording was played back at low speed, both amplitude and pitch of the signal were reduced, making it very hard to copy. To address the problem of reduced amplitude, a Federal technician, Charles Logwood, was given the task of coming up with an audio amplifier. Logwood brought the problem to de Forest, who suggested that, while his audion tube was patented as an amplifier, he had never actually made it work as such. A group composed of de Forest, Logwood, and Herbert Van Etten went to work making an audio amplifier using de Forest's tube.

With the audion tube and considerable tinkering, the Federal team demonstrated that they could amplify the sound of a ticking pocket watch by a factor of five, driving a pair of headphones. The date of this discovery was August 3, 1912. Three days later, input and output circuits of the amplifier were coupled together to provide oscillation.

## THE DE FOREST THREE-STAGE AMPLIFIER

In September, Federal built a three-stage audio amplifier and demonstrated it to the U. S. Navy. It was tested by Dr. Louis Austin of the USN Telegraphic Laboratory and was found to have a gain of 120 times. Then, in October, de Forest took the audion amplifier to New York and demonstrated it to officials of the American Telephone and Telegraph Co. After tests, AT&T bought exclusive rights to the use of the audion in all fields, except wireless telegraphy and telephony, for $50,000.

With new money in his pocket, de Forest left Federal, returning to New York to work on the use of his audion in talking motion pictures. He had accomplished much in Palo Alto in only two years, and Federal was left with the shop rights to his discoveries - rights which would turn out to be very important. Later, in 1914, AT&T would pay de Forest an additional $90,000 for nonexclusive rights in radio telephony, and still later $250,000 for all remaining rights.

## BIGGER ARC TRANSMITTERS!

During the years that de Forest and his companions were devoting full time to the audion amplifier, the rest of the Federal plant was busy making more powerful arc transmitters. The 60-kW arcs for the San Francisco - Hawaii circuit had not performed up to expectations, and it was felt that more engineering talent was needed on this effort. In September, 1912, Federal hired Leonard Fuller, fresh from Cornell University and a short stint with the National Electric Signaling Co. (NESCO), where he had done some development of Poulsen arcs.

By early 1913, Fuller was appointed chief engineer and a systematic research program had been started to understand the nature of the arc, which was a puzzle to even those who used it. By January, 1914, it was possible to replace the 30-kW arcs at San Francisco and Hawaii with 100-kW units. The new transmitters made daylight communication reliable on the trans-Pacific path. (The 60-kW units that had replaced the 30-kW arcs were found to give no more antenna current than those they replaced, and so the stations had gone back to the original units.)

## THE NAVY TEST

What made the development of the 100-kW arc a necessity was some work done by Elwell in 1912 in equipping the U. S. Navy's Arlington (VA) station with the largest arc (30 kW) that Federal had been able to build. The Navy, and its technical expert, Dr. Austin, were skeptical of the arc, since its larger Fessenden rotary-spark transmitter of established design would put twice as much RF current into the antenna as would the Federal arc (100 amperes vs. 50).

The test of arc vs. spark at Arlington was very convincing in favor of CW [8]. The first attempt to raise the Federal station in San Francisco with the Arlington arc was immediately acknowledged, and when the Federal station in Hawaii was called, it turned out that Hawaii had been "reading the mail" and promptly broke in with congratulations and a signal report! [3].

## HIGH-POWER SUCCESS!

The Navy brass was considerably impressed and immediately ordered more extensive tests of the arc transmitter. The USS Salem sailed shortly thereafter from Philadelphia (1913) with a NESCO representative on board, along with a Fessenden "heterodyne" receiver and a Federal "tikker" receiver. The Federal arc consistently outperformed the higher power spark transmitter all the way to Gibraltar. Austin also sent a trusted assistant to Key West, Florida and then to Colón (Canal Zone) to check the signal levels of the arc and spark transmitters. Again, at these tropical sites, the arc was the winner.

In April, 1913, when the report of these tests was submitted to the Navy brass by George H. Clark, the Navy's first civilian radio aide, he made a glowing statement [3]:

> The use of the heterodyne receiver . . . transfers all of the advantage of the spark system to the arc . . . the combination of the heterodyne receiver and the arc transmitter constitutes the most noteworthy advance in the development of practical radio communication that has been made in the history of the art.

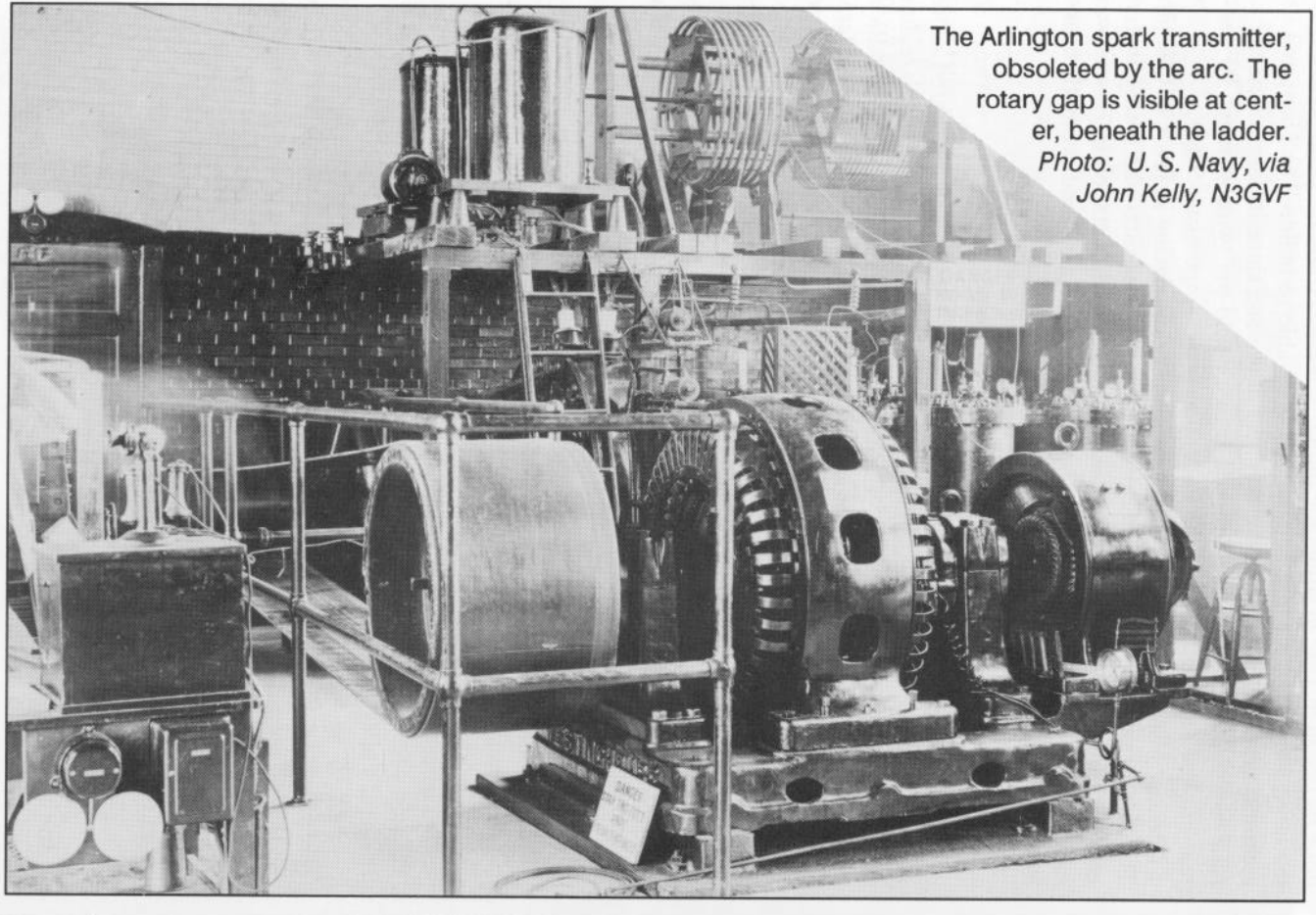
The heterodyne receiver was a Fessenden apparatus, using a small unlicensed Poulsen arc as its local oscillator; which, incidentally, had been developed by Leonard Fuller when he worked for NESCO, prior to joining Federal.

And so on June 30, 1913, as the result of a request for bids by the Navy (preceded by agreement between Elwell and Lt. Cmdr. A. J. Hepburn to draw up the bid request in such a way as to have only Federal as a contender), Federal was given a contract to build a 100-kW arc transmitter for the Darien (Canal Zone) station.

(If it seems that the Navy was bending the rules of procurement a bit, bear in mind that Elwell had no real idea whether a 100-kW arc could be built!)

## EVOLUTION OF THE ARC TRANSMITTER

In the spring of 1913 Elwell had proposed an extension of Federal's radiotelegraph system to include Guam, the Philippines, Japan, and China. The Federal board of directors, however, rejected the proposal, perhaps because of the impending arrival of the Navy contract and the fact that their factory and laboratory facilities were still only a modified garage in Palo Alto.



The Arlington spark transmitter, obsoleted by the arc. The rotary gap is visible at center, beneath the ladder. *Photo: U. S. Navy, via John Kelly, N3GVF*

Elwell could not brook this rejection, and promptly resigned, leaving Fuller to design and construct the 100-kW arcs that Elwell had glibly told the Navy could be built. Happily, Fuller and his arc group were making rapid progress in understanding the basis of higher power level [10]. By January, 1914, two 100-kW units were operating in South San Francisco and Hawaii.

Another (Navy specification) 100-kW arc was placed in service at Darien on July 1, 1915, as a result of the contract negotiated by Elwell in 1913 with the Navy [9]. This transmitter was the largest unit constructed at the Channing and Emerson facility. Arc transmitters above 100 kW required much larger magnet structures involving huge castings - and therefore a larger manufacturing facility.

The new arc in the Canal Zone was a huge success, and three more higher power units were ordered for other Navy stations: a 200-kW arc for San Diego, and two 350-kW units for Pearl Harbor and Cavite (Philippines). With this backlog of orders, Federal started building a new plant in Palo Alto, between the Southern Pacific railroad tracks and El Camino Real. The new plant, first occupied in 1916, had 25,000 square feet of ground floor space, 3500 square feet for second-floor offices, and a railway spur. Now the site of a large Holiday Inn complex, it was just south of the present Palo Alto train station.

## THE ARC AT ITS ZENITH

With the new Federal plant open and a staff of over 200 people, the power level of succeeding arc transmitters grew as business expanded. The San Diego 200-kW station was installed in January, 1917, and Pearl Harbor and Cavite were on the air in December with 500-kW arcs. The latter represented an increase from the original 350-kW specification.

The new Navy sets performed above expectations and the distances covered were unprecedented. The 5300-mile circuit from Cavite to Pearl Harbor, and the 7800-mile path from Cavite to San Diego, were possible with the new arcs. Both were so reliable that the Navy decided that only 30-kW arcs would be required at the Guam and Samoa stations.

Arc construction continued apace at the new Palo Alto plant, with hundreds of units being built, not only for land stations but for shipboard use. By 1918, the list of Navy shore stations using Federal arcs numbered close to 30 (Table 2).

## THE ONE-MEGAWATT ARCS

The pinnacle of the high-power Federal arc was a Navy contract for two 1,000-kW (one megawatt!) units to be installed near Bordeaux, France - the famous "Lafayette Station," one unit to serve as a back-up. The huge transmitters were completed and their installation begun by Federal engineers in 1918, but the Armistice stopped construction until jurisdictional questions could be ironed out. Finally, in December, 1920, the Lafayette station went on the air, operated by the French postal authorities. The station was used as a primary link between France and French Indochina.

Another Navy megawatt station was planned for North Carolina. This unit got only as far as construction of the pair of huge magnet structures in the Federal plant. Completion of these superpower units using 65-ton magnets, sister transmitters to the Lafayette-station pair, was stopped at the end of the war. The

500-kW arc converter and control console
*Photo: Federal Telegraph Co., via Bruce Kelley*

Ernest O. Lawrence's 37" cyclotron on display at U. C. Berkeley
*Photo: H. Olson*

magnet castings lay in storage at Federal until 1931, when Dr. Fuller (who had received his Ph. D. in 1919 from Stanford) arranged to have one transferred to the University of California (Berkeley) and the other to Stanford.

## A NEW USE FOR THE ARC MAGNET

Magnet structures from large Federal arc transmitters found their way into various physics laboratories in the U. S. as these transmitters were gradually replaced with tube-type units in the Thirties. One of the magnets from Arlington was turned over to Dr. Joseph Dunning of Columbia University for the cyclotron of the Michael Pupin Laboratory. At this facility the theories of Dr. Lise Meitner were first tested and verified by Niels Bohr and Enrico Fermi, significant early steps in building the atomic bomb. The magnet that went to Stanford went unused. The city of Palo Alto eventually sold it as steel scrap, since Stanford never picked it up from the Federal property.

## THE UNIVERSITY OF CALIFORNIA CYCLOTRON

Once at the University of California, the huge magnet was assigned to Dr. Ernest Lawrence. The magnet made it possible for Dr. Lawrence and his physicist co-workers to make the first effective and useful cyclotron. Lawrence earned the 1939 Nobel Prize for physics using the new machine; several new elements, such as californium and berkelium, came to be named for the place of his work. The "Uranium Project," under Lawrence, was later moved to Los Alamos, New Mexico during World War II, and at that location helped to produce the first atomic bombs, under the direction of Dr. Robert Oppenheimer.

## GARDEN SCULPTURE

The authors wondered what had become of the one-megawatt Federal arc magnet that became a part of Lawrence's 37-inch cyclotron. A search for it around the California Berkeley campus revealed that it is on display at the Laurence Hall of Science, at the end of Strawberry Canyon Road, in the hills behind the campus.

The cyclotron (or most of it) is on display there in a circle adjacent to the visitor drop-off area outside the hall. The base section of the magnet has been replaced by a concrete pad, but otherwise the immense device is in good condition. One can still read the name FEDERAL cast into the top, except that the letters "AL" have been removed. Perhaps this modification was some sort of in-house joke by the physicists, as in "light as a *feder*." (It weighed 65 tons).

## FEDERAL RADIO OPERATIONS, 1913-17

Throughout the period of high-power arc-transmitter development, as Federal's manufacturing branch supplied the Navy with ever-larger units, the point-to-point communications division of the company continued to operate. Some of the routes apparently proved to be unprofitable, and in 1913 the El Paso, Kansas City, Fort Worth and Chicago stations were deactivated. The Pacific Coast stations and Phoenix continued handling traffic. After the Radio Act of 1912, and its implementing act of March, 1913, the Federal arc stations received standard callsigns. The 1916 list of Federal calls is shown in Table 3.

**TABLE 3 - FEDERAL STATIONS IN 1916**

| Call | Location | Wavelength (m) |
|---|---|---|
| KFS | San Francisco, Beach Station | 300-3800 |
| KFU | Portland | |
| KFZ | Inglewood (new in 1915) | |
| KHQ | Phoenix | 3000-3400 |
| KHX | Heeia | 300-12000 |
| KLS | Los Angeles | 300-3250 |
| KSD | San Diego | |
| KSS | South San Francisco | 300-12000 |
| WEP | El Paso (closed in 1916) | 2000-2500 |
| WFF | Ft. Worth (closed in 1916) | 2000-3500 |

**TABLE 4 - FEDERAL STATIONS IN 1921-23**

| Callsigns | | | | |
|---|---|---|---|---|
| 1921 | 1922 | 1923 | Location | Wavelength (m) |
| KFS | KFS | KFS | San Francisco | 300-1800 |
| KWT | KWT | KWT | Palo Alto | 300-15300 |
| - | KOK | KOK | Los Angeles (Clearwater) | 300-1800 |
| - | - | KNR | Los Angeles (Clearwater) | 3375-5500 |
| - | - | KER | Portland (Hillsboro) | 300-1800 |
| KGH | KGH | KGH | Portland (Hillsboro) | 4200-15300 |

**TABLE 5 - IT&T-MACKAY STATIONS IN 1941 AND 1950**

| Call | Location | 1941 | 1950 |
|---|---|---|---|
| DZG | Manila, Philippines | | ■ |
| KEK | Portland | ■ | |
| KFS | Palo Alto | ■ | ■ |
| KLB | Seattle | ■ | ■ |
| KLC | Houston | ■ | |
| | Galveston | | ■ |
| KNN | Honolulu | ■ | ■ |
| KOK | Los Angeles | ■ | ■ |
| KTA | Guam | ■ | |
| KTF | Midway Island | ■ | |
| WAG | Thomaston, ME | | ■ |
| WMEC | St. John, IN | ■ | |
| WSF | New York City* | ■ | ■ |
| WSL | New York (LI) | ■ | ■ |

* Operated from 67 Broad St. 500 kHz only.

Fort Worth (WFF) and El Paso (WEP) had assigned calls in 1913, but were closed by 1916. Apparently, the Chicago station didn't survive long enough to have an official call assigned.

Table 3 shows that none of the Federal arc stations of 1916 operated at wavelengths shorter than 300 meters, that is, none operated above 1 MHz [11]. At that time, wavelengths shorter than 200 meters were considered useless for long-range communication, and so were relegated to the amateurs. More basically, the arc transmitters could not produce high frequencies, probably due to the relatively low mobility of ions in the arc plasma.

## EFFECTS OF THE GREAT WAR

When the United States entered World War I, the U. S. Navy took over all Federal stations and much of the operating gear was transferred to Allied military bases throughout the world. This takeover was quickly accomplished by purchase of the stations, and virtually all of Federal's domestic patents, for $1.6 million in Liberty Bonds.

This move by the U. S. Navy was expedited to prevent the British Marconi Company from buying Federal for a tendered amount of $1.65 million. The Navy purchase was apparently made hurriedly and without the legal "i"s dotted and "t"s crossed, and created a financial scandal in May, 1918. There was a congressional investigation into charges of bribery, and the president of Federal, Washington Dodge, shot himself in the elevator of San Francisco's Exposition Building. The charges were never substantiated and the investigation gradually faded into limbo.

Moves such as the outright purchase of Federal by the Navy were not done in isolation; there was a general feeling in the Government that foreign ownership of radio stations in the U. S. had to be quashed. Telefunken's Sayville (Long Island) station was closed down with some clever legal moves before U. S. entry into the war, and the other German-installed station at Tuckerton, N. J., was denied a license. (Later, RCA was created out of G. E. and other companies, essentially to push the Marconi interests out of the country. Such events would hardly have been legally possible in peacetime, but were deemed necessary and feasible as the U. S. went to war.)

The U. S. appropriated the German stations once Uncle Sam came into the war. In fact, it was alleged that the Sayville station had been sending coded messages to Nauen, Germany for some time before the U. S. entered the war, using Morse code speeded-up and received via the Telegraphone. It was suspected that the Sayville station sent the coded information that made the German U-boats aware that the Lusitania was carrying a clandestine cargo of munitions to England [12]. Very quickly Sayville and Tuckerton came under the U. S. Alien Property Custodian. They were subsequently operated by the Navy as NDD and NWW respectively.

The Federal Company retained its manufacturing and engineering facilities and its foreign rights. The Navy buy-out enabled Federal to pay off an outstanding indebtedness of $600,000, to continue to make radio equipment, and to expand its plant further. Federal engineers were drawn upon to install and operate the equipment "liberated" from Federal stations and moved to new loca-

tions, as the war effort demanded. (There is some evidence that one of the arc transmitters from Heeia was moved to Vladivostok, Russia with the U. S. Expeditionary Force in Siberia at the close of WW I.) In any event, as a manufacturer of radio equipment, Federal became the principal supplier for the Navy and maritime services during the Great War while its radio circuits languished.

## POSTWAR REORGANIZATION

During the war, Federal's communication branch continued in skeleton form, sending messages along the Pacific Coast using leased wire lines. However, after the end of hostilities, the Government restored to Federal all of its patent rights. With its debts paid off and with profits made during the war, Federal was in a good position to rebuild its point-to-point and marine radio system.

In 1920 the new president of Federal was R. P. Schwerin, under whom a second company reorganization took place. The holding company, Poulsen Wireless Corporation, was finally shed completely and Federal Telegraph Company became the official name.

Haraden Pratt came to Federal as an assistant engineer in January, 1920, and was involved until 1922 in a new installation at Palo Alto, call sign KWT. He had been a ship operator before licensing was required, and one of the first operators licensed in San Francisco. He later graduated from U. C. Berkeley as an engineer. The site was located in an area now generally bounded by Embarcadero Road, Highway 101, and the Palo Alto Yacht Harbor, although it originally extended west of the highway.

Pratt also supervised installations near Los Angeles, at Clearwater (now named Paramount), callsigns KOK and KNR; and Hillsborough, Oregon (Portland), callsigns KER and KGH. These stations had two calls each because point-to-point and marine facilities had to be licensed separately. Pratt also had the original KFS at Ocean Beach reactivated.

When the Palo Alto station was built, the old South San Francisco arc station was converted to a receiving site. (The site is right on the Daly City - South San Francisco line and appears to have been the location of "PH," which in 1914 went on to become KPH at Bolinas.)

Pratt worked for a two-year period, to return years later as vice president.

The experience with the excellent ground conductivity afforded by the salty Beach Station site was probably a consideration in choosing the Palo Alto marsh site. In addition, it was close to Federal's manufacturing plant. This new site became known by its mnemonic wire call MX ("Marsh Xmtr"). Similarly, the receiving site in Daly City was identified by its wire call, DC. DC was built at the former Federal transmitting site "South San Francisco," which had had the call KSS.

MX and DC were connected by leased telephone lines. The separation of over 20 miles allowed full-duplex operation from the main office in San Francisco in the Hobart Building (wire call HB) on Market Street.

At MX a 625-foot steel tower was erected along with many wire antennas. A small transmitter "shack" with traditional California tile roof was built to house the arc transmitters, auxiliary equipment, and technical staff. The large tower was taken down in 1963, but its foundation still proclaims the date of birth, 1921.

The tower was uninsulated and grounded. It supported various antennas in the MF, LF and VLF bands. Six radial guy wires from the top were used to support cage antennas. Each cage employed circular spreaders to configure parallel wires, forming a "fat" vertical monopole. This provided a broadband antenna; and the high capacitance to ground made smaller series loading coils possible.

Other West Coast stations were put back on the air in an attempt to regain the prewar point-to-point telegraph business. The stations operated by Federal from 1921 to 1923 are listed in Table 4.

It is apparent from this list that the Los Angeles and Portland stations were rebuilt at new locations from those before the war. It also appears that the Beach Station, the only station actually in the City and County of San Francisco, soldiered on for a few years after the Marsh Station was operating in Palo Alto [11].

## FREDERICK A. KOLSTER AND HIS LOOPS

Frederick A. Kolster joined Federal in 1921 as Chief Research Engineer after leaving the National Bureau of Standards, where he had been chief of the Radio Section. His main interest was radio direction finding and use of a sense antenna to eliminate the 180° ambiguity of the unaided loop.

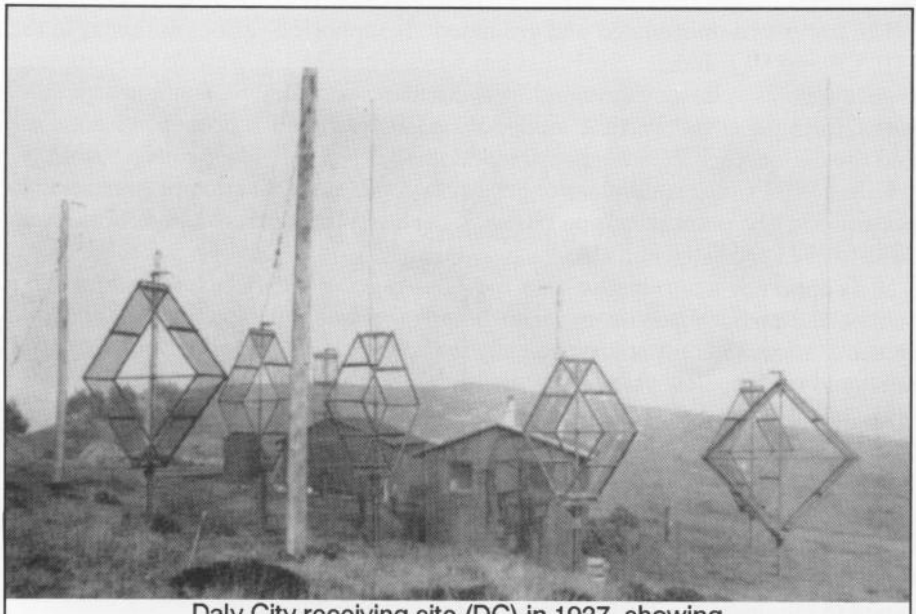
A faded 1927 photograph of the Daly City receiving site shows the original 440-foot towers of the old arc station (PSC/KSS) in the background and six or seven very large, square loop antennas. The Kolster loops appear to be about 10 feet on a side with multiple turns, so are clearly not for HF work. They were most certainly used for the longer wavelengths of the arc stations still in use at the time. The fact of so many loops, all in different orientations, suggests they were used for point-to-point circuits.

The photo shows the influence of Kolster in trying to provide the site with some directional selectivity to reduce interference.

## FEDERAL, MACKAY AND ITT

To understand how Mackay Radio found its way into the Federal-KFS story, it is necessary to go back to the 19th Century. One of the adventurers who became rich in the famous Comstock gold-mining boom was one John W. Mackay. He foresaw a future in wire telegraph communication and became Western Union's principal competitor. His companies, Postal Telegraph and Commercial Cable Corp., spent millions of dollars to lay undersea cables across the Atlantic and Pacific oceans, as well as building wire facilities across the North American continent via Canada. John Mackay never lived to see the Pacific cable finished, but his son Clarence completed it in 1903. (Western Union, however, had been first to complete a continental telegraph line in 1861. Western Union was indeed a union; that is, it was created by absorbing literally hundreds of smaller independent telegraph companies [13].)

In 1927, Federal signed a 21-year contract with Postal Telegraph - Commercial Cables (which comprised the Mackay system) to devote its patents, manufacturing and engineering facilities to supply the Mackay companies with equipment to begin a land and ocean radio service to compete with existing radio services. The first step in this agreement was to have Federal sell its Pacific Coast point-



Daly City receiving site (DC) in 1927, showing
seven LF receiving antennas in various directions
*Photo: American Cable and Radio News, Vol. XI No. 2, March-April 1964.*

LO site south of Half Moon Bay, as seen today from hill south of Tunitas
*Photo: John Brundage*

to-point radio system outright to Mackay. At this juncture, Federal became a solely manufacturing and engineering firm, and Mackay took over all radio operations.

## THE VACUUM TUBE THREATENS THE ARC

Although several of the post-WW I stations had been fitted with Federal arc transmitters, the new tube transmitters were the wave of the future. Looking ahead, Federal began to build them, as well as the time-proven arcs. As early as 1926, Federal had a 500-watt tube transmitter in production [7].

In 1927, Charles V. Litton, the later founder of Litton Industries, was hired to set up a laboratory to design and build Federal transmitting tubes; his main thrust was to design them in such a way as to avoid infringing the patent pool of RCA, which comprised the tube patents of AT&T, GE, Westinghouse, and Wireless Specialty Apparatus.

The services of F. S. McCullough were also obtained to design transmitting tubes. (This engineer is better known for development of AC-operated receiving tubes; he was not the McCullough who helped to start Eitel-McCullough, whose tubes appear to be of a much different design.)

On March 21, 1928, the entire Mackay system merged with International Telephone and Telegraph (IT&T). During that same year, Haraden Pratt returned to the company as vice president and chief engineer of the radio communication subsidiary. Dr. Fuller was vice president of the Federal (engineering and manufacturing) division.

## THE FEDERAL MOVE TO NEW JERSEY

In the summer of 1931, the Federal division moved from Palo Alto to Newark, N. J. The Mackay communication division was the only part of the original combine left on the West Coast. Mackay continued development of its point-to-point system, and as HF became increasingly dominant over long-wave, tube transmitters increasingly replaced arcs. At the Palo Alto site in 1937, for instance, only one arc of the original six remained. Federal made all the tube transmitters for the Mackay system, as by now it had transmitting tubes designed by Litton that could compete with anything made by RCA. The "shop rights" obtained as a result of de Forest's 1911-12 work put Federal in a good position to manufacture tube-type transmitters.

## THE ECLIPSE OF THE ARC

Amateurs and other short-wave experimenters discovered that, using the ionosphere as a medium for "skip" (i. e., refracting signals through the "Heaviside" layer), they could achieve long-distance communication with much lower power than with longer wavelengths. In addition, summer static was much less of a problem on the shorter waves. So the days of the arc transmitter were numbered; tube transmitters generated HF waves efficiently. Of course, tube transmitters could also be made for LF and MF waves, with the advantage that the design provided frequency stability, freedom from near-carrier noise and ease of keying or modulation. Earlier, at low frequencies the Alexanderson and Goldschmidt alternators had become competitive with the arc.

## THE ALTERNATOR OUTLASTS THE ARC

The Federal arc transmitter, unlike its CW competitor, the alternator, was not easily keyed in an on-off (A1) mode. The arc, once started and adjusted, had to be left running. The only simple option for keying was to short out part of the series antenna inductor when the key was closed. This was done using a heavy keying relay. The effect was to shift the transmitter frequency lower when the key was closed. This had the disadvantage of occupying twice as much spectrum space as was needed, since the "back-wave" contained no useful message information.

Thus, the arc stations did not use conventional (A1) mode to send Morse code, but rather a form of frequency-shift keying (F1). Some operators, probably for their own amusement, became adept at reading the "back-wave" by retuning their receivers to the reverse frequency.

Aside from this being an interesting pastime, some of the operators noticed that there were occasional differences in the propagation characteristics between the intended transmission frequency and the "back-wave" frequency, and that the better one could be used for reception as radio propagation conditions changed. Even so, the arc was a frequency "hog" in the long run, and was doomed to obsolescence.

The arc transmitters used a very simple method of antenna coupling. In fact, it was the feedpoint capacitance of the antenna (short compared to a quarter wavelength) and the series loading coil that determined the wavelength of transmission. Such a simple tuning scheme was used to avoid the Marconi patent (British No. 7777) on inductive coupling to an antenna by means of a resonant transformer. When Leonard Fuller was hired by Federal in 1912, his first job was to become fully informed of the Marconi "four sevens" patent, and to design Federal arc stations so as not to infringe it.

The relatively pure CW output of the Poulsen arc transmitter was an asset in using a simple series-resonant feed system because the greater selectivity of a resonant transformer was not required to narrow the broad spectrum of a spark transmitter.

The 1-MW arc transmitters for the Bordeaux station were in operation by 1920, but by this time other technology was gaining on the arc, so no larger unit was ever built. But Leonard Fuller had plans to build arc transmitters as high in power as 5 MW if the requirement arose.

The U. S. Navy and other services continued to use VLF-LF frequencies long after the arcs had been retired. The Navy replaced them with Alexanderson alternators that were used through World War II on frequencies in the 14-30 kHz range. Even after WW II, operation continued on the lower frequencies because their unique properties permit communication with submerged submarines. The alternators, however, were phased out in favor of high-power tube-type transmitters (Cutler, Maine and Jim Creek, Washington, for example).

## THE "NEW" KFS

As HF became the dominant frequency range for long-distance communication, and tube transmitters replaced arcs, changes were rapid at the Marsh transmitter site. The buildings and antenna systems were enlarged in 1928 and

1935. Between these site improvements, the receiving location was moved in 1932 from Daly City to just south of Half Moon Bay, at Meyn Road. This site had a wire call of LO after Lobitos Creek, which runs down the southern boundary of the ocean-front property. The receiving station at Daly City was then sold to Press Wireless.

With the coast mountains now between MX and LO, full-duplex operation became much easier, even as the HF power levels at MX moved into the tens of kilowatts. The new receiving site was free of the manmade radio noise of the Bay Area communities. Its location high on a cliff above the Pacific was ideal for the increasing volume of ship-to-shore traffic.

During the expansion of KFS and its sister stations into the HF region during the Thirties, a whole new array of HF antennas was required. Haraden Pratt hired a White Russian emigré named André (Andrew) Alford to design them for the IT&T-Mackay shortwave installations. Alford was an innovative designer in a day when antennas were thought of in terms of "how high and how much capacitance to ground?," with little consideration given to directivity or other now-common parameters. After his period of antenna-design work for Pratt, Alford went on to design an early instrument landing system (ILS) at Indianapolis and became a group leader during WW II at the Harvard Radio Research Laboratory (with Dr. John Kraus working for him). Kraus said of Andrew Alford, "He is to antennas what Sikorsky is to aircraft" [14].

## THE COMMUNICATION SYSTEM CALLED KFS

Until WW II, the IT&T-Mackay communication system in the San Francisco area continued to handle a mix of point-to-point and ship-to-shore messages with its sites MX, LO and HB. (The San Francisco office, HB, moved from the Hobart Building to 22 Battery St.) Collectively, the system was called KFS, although only the Palo Alto transmitting site had a callsign. The Beach Station callsign KFS was transferred to MX and the original MX call of KWT dropped in 1924.

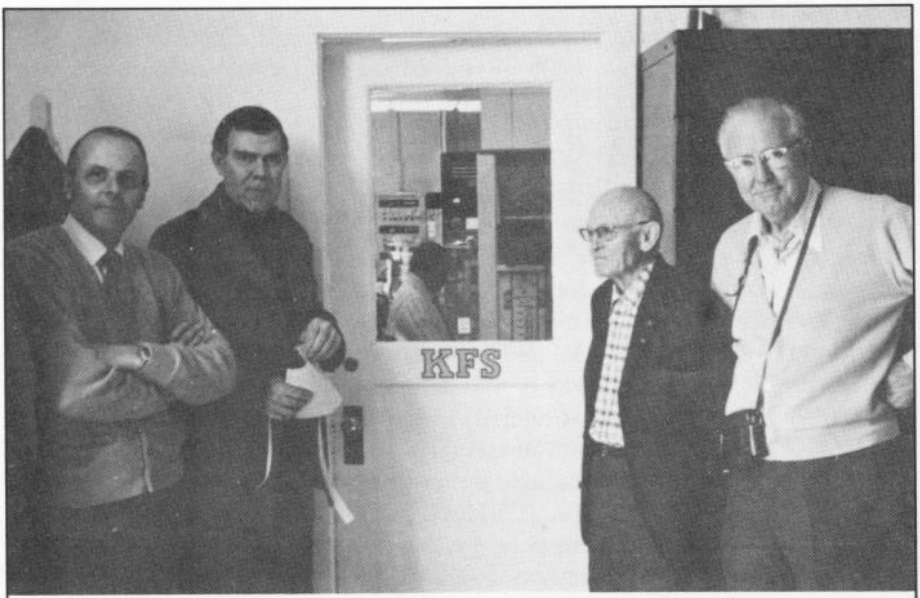
Relocation of the San Francisco area system was only what was happening locally. IT&T-Mackay also was busy at this time setting up other stations around the U. S. and its possessions. Some of them were simply rebuilt from locations operated before WW I; others were new, expanding the IT&T-Mackay system in both point-to-point and marine communications.

By 1941, the IT&T-Mackay array of stations (by now essentially all on HF frequencies, except for the marine band around 500 kHz) was as shown in Table 5. The VLF band with its high-power arcs had been replaced by MF-HF with vacuum-tube transmitters.

The Mackay stations all had "W" or "K" callsigns; that is, they were all in the U. S. or its territories. However, since IT&T had acquired All-American Cables in 1927, some stations operated under foreign license, for example, YNL, YNR and YNU in Managua, Nicaragua; and OCJ and OCK in Lima, Peru. (Most of the calls in Table 5 and listed above were obtained from Reference 15.)

## "A DATE THAT WILL LIVE IN INFAMY"

With the onset of WW II, all coastal stations in the U. S. changed their mode of operation drastically. The stations either shut down or came under the con-




A 1975 view at the KFS operating room in Palo Alto: John Brundage, station manager; Bruce Kelley, W2ICE; Eben Cady, retired station manager; and Thorn Mayes, W6AX
*Photo: Warren Green, W7JY, from OTB, Vol. 16 No. 2 (Sept. 1975)*

Base of old "MX" 625-foot tower, erected in 1921 and taken down in 1963, with Rex Patterson, W6VJJ, and Hank Olson, W6GXN
*Photo: H. Olson*

trol of the military. In the case of KFS, the operators were inducted into the U. S. Coast Guard, and the station taken over by that agency after proper USCG-Mackay negotiations. At that time, the Chief Operator at LO was Eben K. Cady, who wrote Reference 16.

The first inkling that KFS Marine Radio had that war was starting for the U. S. happened at 10:50 AM PST on December 7, 1941. The 500-kHz• operator heard a clear signal SSSS SSSS SSSS ("submarine sighted") DE CYNTHIA OLSON (callsign unknown). The ship gave her position as 750 miles southwest of Seattle. The SS Lurline (KIEK), enroute from Honolulu to San Francisco, was about 1300 miles southwest of San Francisco. Also hearing the distress call from the Cynthia Olson, KIEK asked "Is the sub surfaced?" The latter replied, "R (yes) WAIT - SSSS SOS SOS SOS POSN - -." The signal faded out. That was the last heard from the ship and its crew [16].

The Lurline and the Cynthia Olson were both heard by KPH (the RCA marine station at Bolinas, CA) and by KTK (the Globe Wireless operation at Mussel Rock) as well as KFS. Shortly thereafter, KFS received a message from the U. S. Navy to relay to the Lurline, directing her to proceed directly to San Francisco. In addition, KFS was directed to close down automatic keying (VVV DE KFS) and transmit only on orders from the Navy.

Shortly after the Cynthia Olson emergency, the KFS staff learned of the bombing of Pearl Harbor.

## THE GUERRILLAS

The wartime routine of KFS was interrupted in mid-August, 1942, when the operators began hearing strange signals in the 8.3-MHz marine band. The signals were weak and unidentified and sounded like someone tuning-up a transmitter [16]. The beam antennas at KFS indicated the signals came from the Far East, possibly the Philippines. A 24-hour watch was set on the signals, and finally in late August or early September, a weak signal WAR DE KAA was heard by KFS operator Arthur H. Hart. Since KAA had been the call of RCA's Manila station, demolished by the Japanese invaders, and WAR was the U. S. Army's headquarters station in Washington, Hart felt something important was going on. He quickly reported the intercept to Navy station NPG at Mare Island (in the S. F. bay area), suggesting that "KAA" be called and told to listen for KFS.

About 3:00 next morning on 8330 kHz, KFS heard KAA calling, and having permission from the Army to acknowledge transmissions, was able to accept the clear-text message of KAA. The first contact read something like:

> KAA DE KFS - GM QSA 2 BUT QRK K ("your signals weak but we read you OK go ahead").
>
> KFS DE KAA - GE THIS IS GEORGE GOULD. WE ARE A BUNCH OF GUERRILLAS IN THE MOUNTAINS OF NORTHERN LUZON. WE HAVE A BREADBOARD XMTR AND RCVR WHICH WE CARRY ON OUR BACK. THE JAPANESE ARE MOSTLY IN THE CITIES AND ALONG THE COAST BUT THERE ARE PLACES ALONG THE NORTHERN COAST WHERE IT WOULD BE SAFE FOR A SUB TO LAND. WE NEED EVERYTHING. WE WANT SMOKES BUT OUR DIREST NEED ARE SHOES. AR K.

KAA DE KFS R R R QSU TMW?" (OK see you tomorrow?).

KFS DE KAA R R R (OK).

There followed an elaborate question-and-answer procedure to make sure that the KAA people were who they said they were, and that the whole operation was not a disinformation scheme of the Japanese. When General MacArthur in Australia heard of the first messages from the Philippine guerrillas, he was elated.

KAA was soon off the air, as the Japanese captured the group, executing some and imprisoning others. George Gould was at the KAA key during much of the question-and-answer period with KFS, and spent the rest of the war in a Japanese prison camp.

Another guerrilla transmitter took up the slack, calling itself "WPI." The staff at KFS were quickly augmented by an Army colonel, Irving Kaufman, to "wring out" the new contact. Kaufman had been an operator on the SF-Manila circuit of Globe Wireless. The procedure involved personal recognition at each end of the operator's "fist," intimate personal details known to each other (having communicated before the war), and use of certain antiquated abbreviations in American Morse code. Col. Kaufman quickly accepted the authenticity of WPI and, as time went on, WPI passed a lot of valuable information in plain language out of the Philippines via KFS, especially concerning distribution and numbers of Japanese troops in the Luzon area. But one day, WPI fell silent. The loss of WPI was due to a reorganization of the various Philippine guerrillas into a coordinated command, designated the IV Philippine Corps. This group had more expertise, plus a cryptographic device (M-94), and other communication equipment built from parts stolen from Japanese spares stores.

In October, 1942, KFS heard "WPM" (the IV Corps) calling it in plain language in the 8.3-MHz marine band. WPM was instructed to use the M-94 device, using information thought to be available only to the guerrillas:

WPM DE KFS BK THE CODED MESSAGE USING AS KEY WORD IN COMBINATION CIPHER DEVICE MIKE NINE FOUR FOLLOWED BY DOUBLE TRANSPOSITION THE NAME OF PLACE WHERE PRESIDENT QUEZON AND GOVERNOR CONFESOR LAST DINED TOGETHER K

It took quite a while for WPM to get the people together who knew what the code word might be. The correct key, PANUBIGAN, was figured out, and messages began passing at a great rate to KFS and to MacArthur's station KAZ in Melbourne, Australia. The traffic at KFS became so heavy that the Army sent a contingent of its own operators and technicians with their equipment to augment operations. KFS became a very crowded place overnight. This mode of operation continued until December 16, 1944, when the Philippines were liberated. Then, on January 1, 1945 the KFS staff were all given honorable discharges from the Coast Guard.

## KFS SERVES THE WAR EFFORT

KFS rendered many other services to the war effort, including handling traffic for the Air-Sea Net for the area between Nome, Alaska and Panama. A constant guard was mounted on 500 kHz to intercept distress signals. Many signals were picked up from the poor souls in lifeboats using kite or balloon antennas

and a "Gibson Girl" or other emergency transmitter.

KFS was in a good location to receive these weak distress signals owing to a superb location on the very edge of the Pacific and a sensitive receiver that had been built at the site by the manager, J. O. Watkins, in the Thirties. The set had three stages of RF amplification and two IF stages. This meant that it was good on sensitivity but poor on dynamic signal range. During the war years, with little traffic on and around 500 kHz, it became the very thing that was needed to "dig out" the weak emergency signals. Many people adrift at sea owed their lives to this "home-brew" receiver [16].

## POSTWAR COMMUNICATION EXPANSION

The post-WW II period was a time for IT&T-Mackay to regroup. Stations taken over by the government "for the duration" had to be returned to commercial operation or dropped. Because the war encompassed one of the most inventive periods in electronic communication, the customary ways of handling a large volume of traffic changed dramatically. For example, postwar undersea cables were no longer limited to bandwidths of a few hundred Hz and therefore suitable only for high-speed machine transmission. The new cables handled multiple voice channels. In addition, satellites eventually provided greater bandwidths for communication, even television signals and various pulse-code modes of communication.

The situation became even more competitive with regard to point-to-point links across the U. S. continent, where microwave relay stations were rapidly installed. These links provided tens of MHz bandwidth for TV or other wideband signals. The channel capacity continued to expand with the rapid installation of fiber-optic lines, having bandwidth figures in the thousands of megahertz.

With these competitive modes of communication coming on so rapidly after the war, the HF point-to-point business was essentially finished by the mid-1960s. This had a withering effect on shortwave operations such as Press Wireless because it had no ship-to-shore business to balance the traffic losses in point-to-point service.

The post-WW II list of stations in the IT&T-Mackay system was somewhat smaller than, and different from, the prewar list, as a comparison of the 1941 and 1950 entries in Table 5 will show. The Texas station (KLC) was moved from Houston to Galveston, the Pacific island stations on Guam and Midway discontinued, and a new station set up in Manila.

These changes signify an abandonment of point-to-point work in favor of ship-to-shore service. So stations, if moved, were moved toward the sea.

## KFS, GLOBE WIRELESS, AND RCA PATENTS

In 1960, in a consolidation move, KFS acquired Globe Wireless (including its local station at Mussel Rock, now called Pacifica), followed by Press Wireless (Belmont, CA) in 1967. Some of the personnel and equipment were integrated into the operations of KFS with each acquisition. The KTK callsign of Globe Wireless continued to be used at the LO and MX sites, as well as KFS. After 1967 only KFS was used, as point-to-point service was discontinued.

Before 1960 the MX site used transmitters built by Federal, using tubes de-

Transmitter gallery at MX site (Palo Alto) in 1993,
showing six of thePW-15 transmitters.
*Photo: H. Olson*

Harris transmitters at MX site: at far left, for 600-meter CW;
at right, high-frequency autotune unit for SITOR
*Photo: John Brundage*

signed by Charles Litton and circuit techniques chosen so as not to infringe the patent pool of RCA. Since crystal oscillators couldn't be used for patent reasons, free-running oscillators were carefully designed and built in temperature-stabilized boxes. Transmitter neutralization couldn't be used either, so the Litton water-cooled triodes were operated in grounded-grid configuration.

The major equipment acquisition from the formerly competitive stations was the complement of PW-15 air-cooled 15-kW transmitters from the Globe Wireless and Press Wireless sites. These units were reinstalled at Palo Alto.

Although the dozen PW-15s were put into service in the '60s, it was not until 1979 that they were updated to meet newer FCC requirements. Directing this transmitter-upgrade project and the design of new antennas (following removal of the 625-foot tower) was an innovative Stanford engineer, Kent Wilder. Kent was with KFS-IT&T-Mackay from 1951 to 1985. He and Dr. William Ayer also created the VHF modeling range on which most of KFS' newer antennas were developed.

The twelve PW-15 transmitters are still in use at KFS in 1993, on the fixed frequencies for which they meet type acceptance. (In fact, they are "cleaner" with regard to near-carrier noise sidebands than many modern transmitters using synthesizers, since each PW-15 uses a crystal ground for the authorized frequency.) They are presently in use on six HF marine frequencies, each channel having a backup transmitter.

## KFS DURING THE EIGHTIES

In the Eighties, ITT (as then identified) began selling its stations, which were essentially all ship-to-shore operations. In 1985 WSL (Long Island) was closed down, and one of the KFS staff packed a large truck with residual equipment and drove it cross-country to Palo Alto. In 1988, KFS itself was sold to Western Union, into which system much of KFS' radio traffic had been flowing over the years. KLB was sold to a group of its operators in Seattle, who moved it to their own property nearby and resumed operation. The other stations listed in Table 5 were similarly sold during the 1980s.

After two years of operation by Western Union, KFS was bought by another private owner, Ken Jones. The surviving marine station, now known as "KFS World Communications," continues its time-honored business of service to ships using CW, SITOR (error-correcting radio teleprinter), and INMARSAT-A.

On any given day, the staff of three or four operators at the Half Moon Bay receiving site remotely key the transmitters in Palo Alto via multiplexed phone lines, using a hand key (skilled operators use their own "bugs" or electronic keys), or assist in operating SITOR communications. Most messages are handled via SITOR automatically, with operator assistance if required or requested by the ship.

The upstairs area of the Mackay Radio Telegraph Company building at Half Moon Bay (dating from 1932, as its cast-in-concrete facade proclaims) is much different from what it was in the Fifties. The Hammarlund SP-600-JX receivers are gone, and in their place are Watkins-Johnson WJ-8718 digitally tuned receivers and CRT terminals. But the operators are still there with their traditional keys, plus their ability to operate the new computer-controlled modes of com-

munication via satellite.

INMARSAT-A service, for example, is arranged by leasing channels on that satellite from its operator; no satellite up-down link is required at KFS. In fact, the INMARSAT-A capability is part of a "complete maritime package" concept, rather than the main business of KFS. HF communication "is the future" at KFS.

## KFS LOOKS TO THE FUTURE

KFS is not fighting a rear-guard HF action; rather, it has plans to expand into other maritime areas. It has recently acquired a coastal station on the Gulf of Mexico coast (WNU, New Orleans) for handling the busy ship-to-shore traffic of that area. Since KFS already remotely operates its transmitters at MX via multiplexed phone lines and has digitally controlled receivers at its receive site, it is only a matter of implementation to have the Gulf station under the same operator control as KFS in Half Moon Bay. This remote operation of two distantly located coastal stations has already been used on the East/West coast by WCC and KPH, which belong to the MCI Company (a competitor in ship-to-shore traffic) and by the Coast Guard.

## SILICON VALLEY, AFTER ALL

Poulsen/Federal, as created by Cyril Elwell near Stanford University, represents the first wave of a series of events that defined today's Silicon Valley. Elwell's entry into the generation of CW for radio communication was influenced by important Stanford professors, including Charles D. Marx and Harris J. Ryan (heads of the Civil Engineering and Electrical Engineering Departments respectively). This climate of encouragement and support, as well as Elwell's spirit and drive, made the difference and created the first "technology wave" in Silicon Valley. (The only silicon involved in this first wave was perhaps in silicon-crystal detectors, or as an oxide in silica insulators!)

The second technology wave had its beginning, again at Federal, when de Forest, Logwood and Van Etten managed to get the audion to amplify audio signals, and also to oscillate at audio frequencies (1912). The vacuum tube was the "hot new item," the center of technological advances from the Twenties through the Forties. As with most waves of advancement, the second wave was already beginning when the first was near its maximum.

## "COME JOIN THE BAND, AND GIVE A CHEER FOR STANFORD RED"

Stanford, again, was central in providing a nurturing environment, and many of the individuals responsible for the second wave came from its graduating classes. One man, in particular, started his early electronic career as an amateur operator (6AE), graduated from Stanford, got his doctorate from MIT, served as a Federal Company employee, and then become a professor of radio engineering at his alma mater. His name was Frederick Emmons Terman.

Terman is not renowned for a particular invention, but rather for a unique ability to bring together technical people with technical facts and theory (as in his seminal books Radio Engineering and Radio Engineer's Handbook. Some of the names he sponsored and encouraged were William Eitel, Philo Farnsworth, Gerhard Fisher, Edward Ginzton, William Hansen, Ralph Heintz, William Hew-

lett, John Kaar, Jack McCullough, David Packard, and the Varian brothers; who are well known to the communication fraternity. Their names and accomplishments would be associated with the San Francisco area (and Silicon Valley) for years to come. Not all were Stanford men, but Terman and his technical "family" were the nucleus that attracted outside genius to the area surrounding the University.

## THE STANFORD INDUSTRIAL PARK

During World War II, Terman's abilities were harnessed by the Government to form the Radio Research Laboratory at Harvard University. There he collected a staff of technical people of the highest caliber to solve the pressing electronic problems of a high-tech war. The Harvard Laboratory was similar in purpose and structure to the well-known MIT Radiation Laboratory which specialized in radar. The two labs, working together, provided critical contributions in the electronic warfare field.

On his return to academic life at Stanford after the war, Terman convinced the trustees of the university to create an even more fertile field for the growth of Bay Area electronics. A large tract of Stanford land, to the south of the campus, was set aside as a technical industrial park, and arrangements were made for industries which located there to have use of Stanford's extensive library facilities, access to the Stanford program that enabled their workers to obtain in postgraduate degrees, and other benefits.

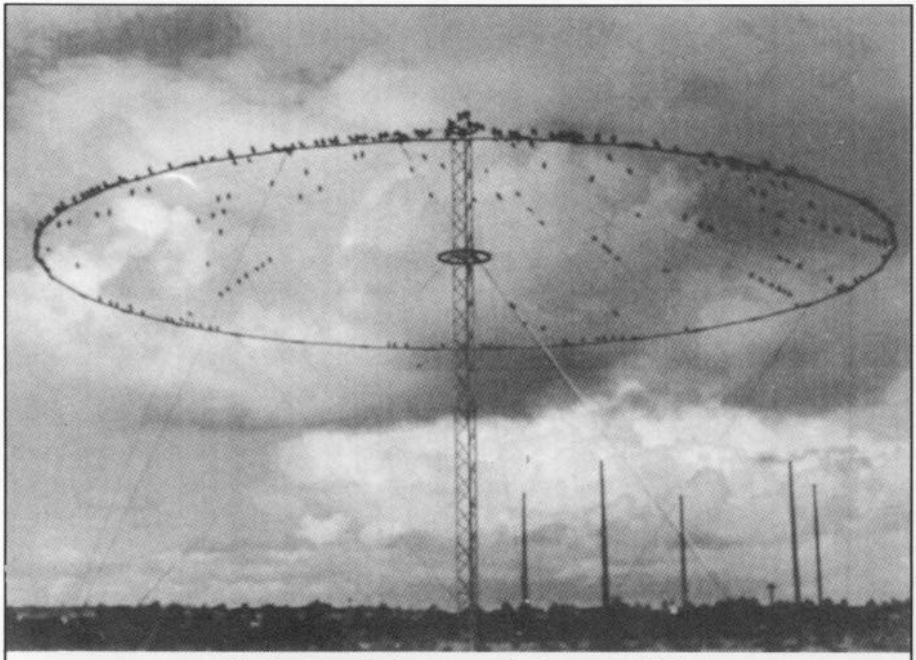
The result of this policy was amazing and swift. By the mid-Fifties, the Park was rapidly filling with high-tech companies: Beckman Instruments, General Electric Microwave Laboratory, Hewlett-Packard, Varian Associates, Watkins-Johnson, etc. Further, at one of the divisions of Beckman, Shockley Semiconductor Laboratories, the third wave of Silicon Valley development, was beginning.

## THE THIRD WAVE

William Shockley, co-inventor of the transistor, had gathered around him some of the brightest and best young physicists and technicians from the East to start a new semiconductor company in Palo Alto, the city of his boyhood. The company was formed specifically to develop the newly demonstrated transistors and semiconductors discovered by Brattain, Bardeen and himself at Bell Labs (for which they were to share a Nobel prize).

Shockley Semiconductor was not a lasting success: the staff that Shockley had brought West quit his firm *en masse*, apparently over a disagreement over company research concerning the four-layer (PNPN) diode. Out of Shockley Semiconductor came Fairchild Semiconductor and other companies. Soon, this third wave of technical advancement gained amplitude and the old, established electronic firms would either adapt to new conditions or perish in obsolescence.

Semiconductor chips were the nucleus around which the third wave expanded. The silicon transistor technology developed at Fairchild by Robert Noyce and others of the "Shockley deserters" team would prove to be crucial to semiconductor development in Silicon Valley. The epitaxial process by which Fairchild made its transistors gave unprecedented gain-bandwidth figures, and also allow-



Vertical conical monopole for 4-24 MHz
at MX site, outlined by roosting birds.
*Photo: John Brundage*

ed complex photolithographic processing. The epitaxial process made it possible to put resistors on chips as well as transistors. Thus Fairchild was among the first makers to produce silicon integrated circuits - resistor-transistor logic ICs. Other digital logic forms followed rapidly at Fairchild, as did linear ICs like the $\mu$A709 operational amplifier.

As ICs became the largest part of the product lines of the many Silicon Valley semiconductor plants, there was a continuing growth in chip complexity. It became possible to put thousands of components on a single chip; not just NPN devices and resistors, but PNP transistors, diodes, zener diodes, capacitors and metal-oxide-silicon (MOS) field-effect transistors.

## THE FOURTH WAVE

The fourth wave began under Robert Noyce with the creation at Intel of the first microprocessor. The $\mu$P was basically a small computer-on-a-chip which, when arrayed with other ICs to store bits ("memory chips"), could be programmed to do logic functions at the command of the memory programmer. The effect of the $\mu$P was profound; no longer did the function of a chip depend upon its manufacturer. The user desiring a particular function could buy a chip (or set of chips) and program them himself. And so, the fourth wave of electronic achievement in Silicon Valley was a programming or software wave for small computers.

Today, the largest effort goes into thought and creation, and not into the physical production of components to accomplish a need. As one might expect, since thought can be accomplished in Silicon Valley or in any remote location, many software companies have left the San Francisco area for less hectic locations. But the cauldron of ideas and innovation continues to boil in Silicon Valley, and many prefer to stay in it, despite congestion and smog. They remain, perhaps to be at the beginning of the fifth wave, which may be the explosion of "personal wireless" communication: an amalgam of computers, cellular phones, voicemail, digital networks, fiber optics and other devices to provide reachable-worldwide personal communications.

And what of KFS? From the early days to the present, in one form or another, it has remained steadfast. Like the rabbit in the television battery commercial, it just keeps going, and going, and going . . .

## ACKNOWLEDGEMENTS

In preparing this article, the following persons were interviewed. Some are current or retired KFS personnel; some are with other San Francisco area radio stations; and others are in the radio-historical field. Our thanks go to all of them, without whose help and encouragement this story could not have been completed. If any error exists in this manuscript, it is the fault of the authors, not the contributors. They are:

Bill Ayer, K6VQ; Dalton Bergstedt, W6AUH; Mort Brewer, W6JU; Bill Breniman, ex-W6BE; John Brundage; Bill Byron, W7DHD; Lewis Coe, W9CNY; Rod Deakin, NR7E; Bud Ferguson, W6VK; Carl Hoeck, WA6NQV; Richard Hoeck, W6RZL; Fred Hoehn, ex-6ATX; Ken Jones; Peter Kierans, VE3OGH; John Kraus, W8JK; Paul Letsinger, W6SYL; Ron Martin, W6ZF;

Rex Patterson, W6VJJ; Ed Prather, W6GXF; Norm Smaha, W6CSI; Kent Wilder; George Wiley, W6VKT; and Frank Wyatt, N6FW.

David Krauss, ex-W7DCP, aided with preparation of the illustrations.

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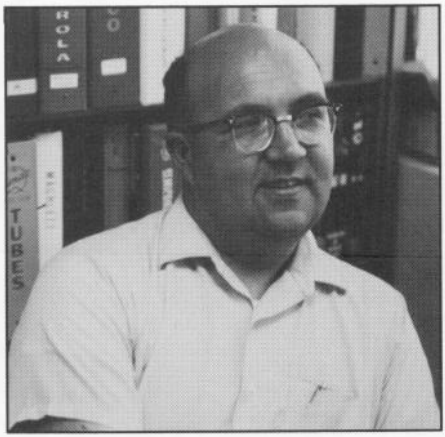
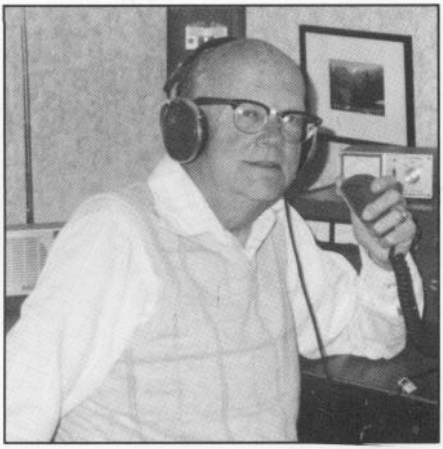
**Hank Olson**




*Hank Olson, born 1931, San Mateo, Calif. Resided in Menlo Park, Calif. from 1936 to the present except for two years at the U. S. Army Electronic Proving Ground at Ft. Huachuca, Arizona. Was fortunate to have Dr. F. E. Terman as instructor in radio engineering. Worked while a student as a research assistant for the Radio Propagation Laboratory at Stanford University under Dr. "Mike" Villard, W6QYT, and Dr. Allen Peterson, ex-W6POH, with Dr. Leonard Fuller as laboratory administrator. Returned to Stanford after the Army, 1956, to work on HF backscatter radar for two years during the International Geophysical Year (IGY), traveling to foreign sites about 40% of the time. Transferred to Stanford Research Institute in 1958 for continuing work with the Radio Physics Laboratory, for 28 years. Licensed as W6GXN, wrote articles for amateur and other technical publications (stopped counting at 150). Taught night classes in electronics at Foothill College. Now consulting in electronic circuitry and researching radio history. Living in Menlo Park with spouse of 33 years, Jane McKenzie Olson. Hobby: tinkering with '56 Austin-Healey and '73 Lotus sports cars.*

**Bill Orr**



*Bill Orr became interested in radio at a very early age when he dismantled his dad's Radiola IIIA to find the little men who were talking and making music inside the box.*

*He was licensed in 1934 as W2HCE, later in 1938 as W6SAI when an undergraduate at the University of California.*

*During World War II, Bill was in the Radio Test Department of Douglas Aircraft Company (Santa Monica) and later in the Engineering Division of Hughes Aircraft Co. He recently retired after 28 years at the Eimac division of Varian.*

*Bill has been active in Project Oscar (now AMSAT) and has been licensed as FP8AC, 3A2AF, KH6ADR, and ZL0SAI. He is the author of many technical articles and books, and is the Editor of the Radio Handbook.*

*He is active on the air and lives with his wife, Sunny, in Menlo Park. Sunny is an accomplished pilot. They have six children, none of whom exhibits any interest in amateur radio.*

Tube collector Howard Schrader, radio pioneer Elmo Pickerill, and collector Joseph Fetsch (left to right) at the IRE Convention in New York, 1957. Display is from the Schrader collection.

# JOSEPH T. FETSCH: VACUUM-TUBE ENGINEER AND COLLECTOR

**Jerry Vanicek**
Chicago, IL

A highlight of a 1950s radio-collector tour would have been a visit to the Navy Yard Tube Museum. This extensive collection was displayed in Building 291 at the New York Naval Shipyard. The curator was Joseph T. Fetsch.

In 1910, growing up in Baltimore, Mr. Fetsch became interested in wireless. His first amateur station consisted of a simple spark-coil transmitter and a receiver using a mineral detector. After transmitting licenses became required, he obtained the callsign 2HU. He studied at Johns Hopkins University under a Maryland scholarship, graduating in 1924 with a degree in electrical engineering. Immediately afterward he joined the engineering staff of General Electric in Schenectady, and was assigned to W. C. White's research area. The two men became friends. Dr. White gave him several 50-watt tubes to test in his amateur station. The result was that by 1925 the station had been heard in Australia. These tubes became treasured possessions. Almost 30 years later Dr. White donated to Fetsch a number of duplicate tubes from the GE Tube Museum.

In 1927, Fetsch accepted a position with the Naval Research Laboratory, working directly under Dr. A. Hoyt Taylor. Fetsch, a vacuum-tube specialist, ultimately became head of the Vacuum Tube Division.

In the 1930s NRL became heavily involved in radar development. Fetsch was a strong advocate of radio direction and ranging of naval guns. At one time during WW II he increased a seemingly large radar-set order nearly tenfold without going through the usual lengthy channels. He recognized the immense pending demand for such equipment and the fact that a large order would be built on an assembly-line basis. The unit cost was thereby decreased by approximately 50%, and the equipment was eagerly received by the allied forces.

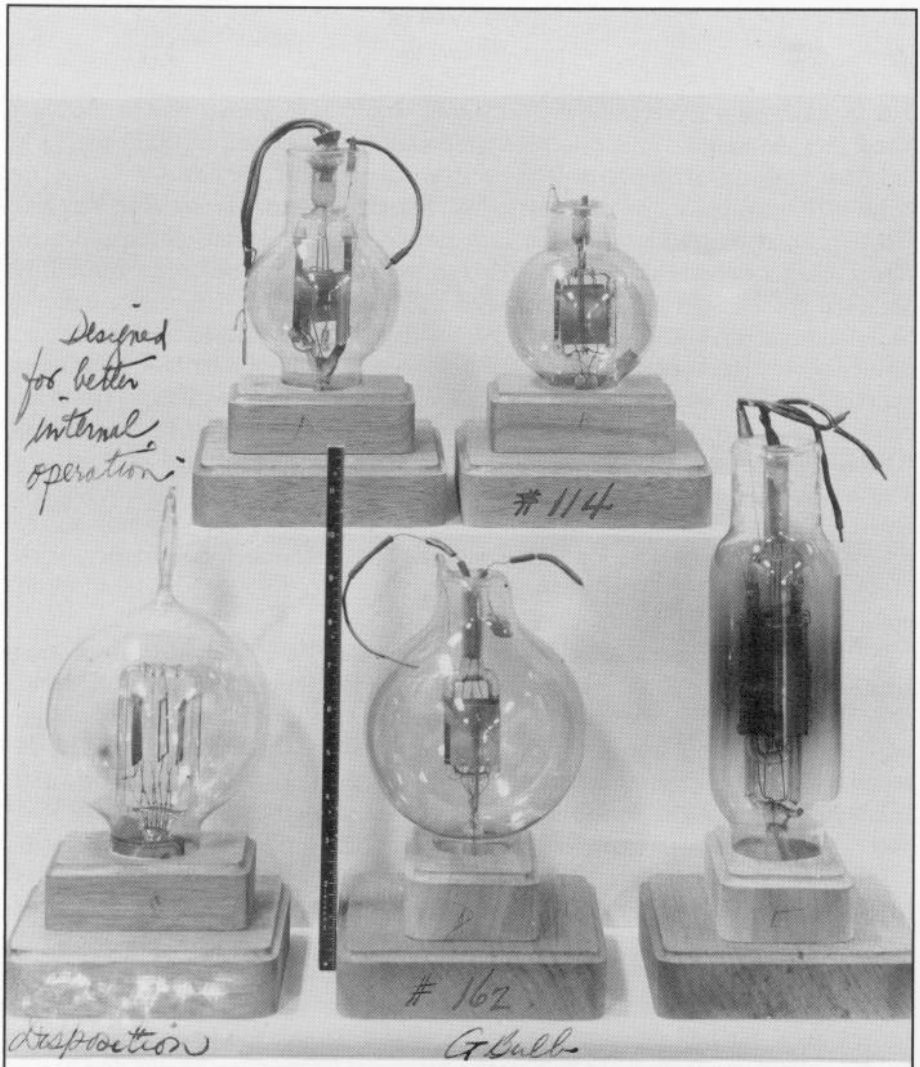
NRL had been founded in 1923. In 1943, Admiral Van Keuren decided that the Laboratory should have a 20th anniversary celebration. Since Fetsch's interest in vacuum tubes was well known, he was asked to display some samples.

About this time, Fetsch became acquainted with Lauren McMaster, ex-1AGS. McMaster had been a production engineer with Raytheon in 1929, later working for Sylvania. He had ardently saved tubes since 1916 and was looking for a home for his collection. Impressed by Fetsch's historical knowledge, he decided to give the collection to him.

As head of the VT Branch, Fetsch evaluated a considerable number of tubes. At the end of the war, captured German and Japanese tubes - magnetrons and the like - were also examined. The Navy discarded these samples after testing. Fetsch personally saved a number of them from destruction.

In 1947, Fetsch and his department were transferred to the Material Laboratory of the New York Naval Shipyard. The tube collection followed. With limited space available for display, the collection had grown to the point where only a fraction of the tubes could be exhibited.

The Navy eventually considered the tube collection to be obsolete. No one was




De Forest Oscillion transmitting triodes, ca. 1915-17, with a foot ruler for size comparison. These came from Dr. L. W. Austin of the National Bureau of Standards. The one at lower left was labeled, on this 1954 Navy photo, "electrode disposition - plate, fil., fil., grid, fil., plate." Note the heavy use of glass arbors supporting the internal elements.

interested in continuing this historical work. On retirement in the early '60s, Fetsch acquired his collection from the Navy.

Some years afterward, Fetsch decided that it was time to inventory and pack his comprehensive collection. It had grown beyond 4000 items, ranging from the Fleming valve and a 1907 Navy audion to the most advanced designs of the '60s. This task took several years before his death.

Fetsch had a love for mathematics. He devoted his remaining years to a theoretical study of prime numbers, but always retained a deep interest in his vacuum tubes and the people he had known throughout his 35-year career in the Navy.


## ACKNOWLEDGEMENT

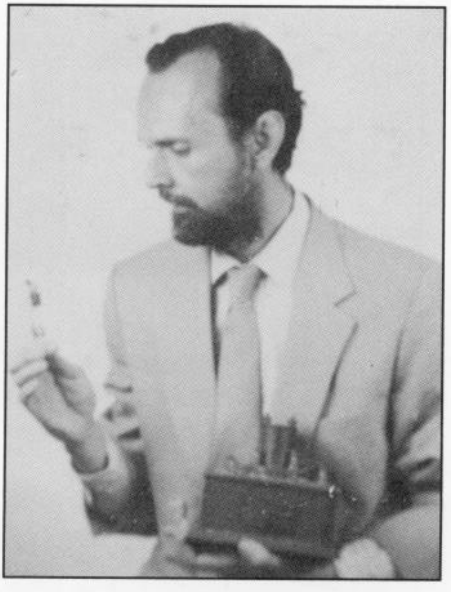
The writer wishes to thank Mr. Thomas Fetsch for providing access to his father's technical files and for answering personal questions.



**Jerry Vanicek**

*Jerry Vanicek is a self-employed electrical engineer who graduated from Southern Illinois University in 1977. He previously held the amateur-radio calls WA9RJD and KC9JS.*

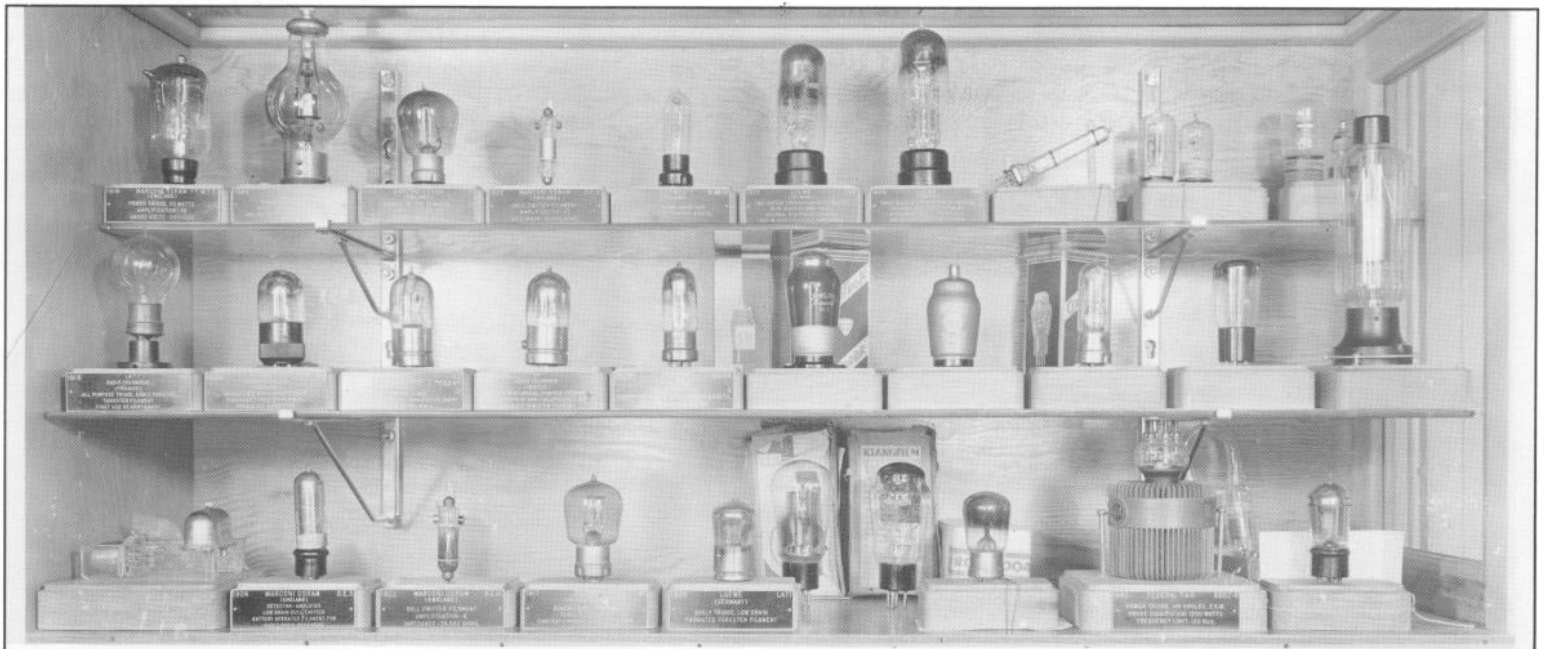
*He became interested in radio history in 1964 at the age of 15. Major interest is in the technical evolution of radio by study of its active circuit element, the vacuum tube.*

Several U. S. Navy photographs are available showing the Fetsch display at the New York Navy Yard while it was being assembled in mid-1955. The tubes were housed in stacking cabinets divided into (at least) 14 units holding three glass shelves each. The tubes had wooden holders with engraved nameplates. The most illustrative photos are presented with this article.

Some of the nameplates pictured contain errors, since the tubes were labeled from the best information available at the time - for example, Tyne's Saga did not yet extend past 1920. In preparing the photo captions, we have given the most accurate information possible.

Items mainly from WW I and the Twenties. **Top Row**: Moorhead (three samples); WE Signal Corps VT-2/Navy CW-931 (three samples); WE VT-1/CW-933 (three samples); WE 201A/-CW-186 (two samples); WE "P" (prototype of VT-3, two samples); GE Type G Pliotron/VT-11; GE CG-1162/VT-14 (three samples). **Center Row**: GE Type U (CD-1144/VT-18), predecessor of the UV-201; WE CW-1818 (211A); GE UV-203; RCA UV-211; RCA UV-217C; WE 211D; Westinghouse CWL-1984 (211); Westinghouse KU-627 grid-glow tube; Westinghouse 872. **Bottom Row**: RCA WD-11; GE CG-20xx; GE CG-2566 (UX-210, mislabeled as Westinghouse); Ken-Rad metal-tube prototype; RCA 871; unident. experimental power triode, 1933; Arcturus Wunderlich detector; 5Z4 (four samples, including the 1935 original tall design); Arcturus 127 carton.



Mostly British, German, French, Dutch, and Swedish tubes. **Top row**, L-R: Marconi-Osram M.T.5 25-watt triode, 1919; Cossor AT50 50-watt triode, 1923; Marconi-Osram T.15 15-watt triode, 1920; Marconi-Osram DEQ detector triode, 1922; Cosmos SP.610/RR output triode, 1928; Loewe 2HF dual-triode and 3NF triple-triode, each with internal R-C coupling, 1926-28; Telefunken Arcotron; four unident. (first and fourth Telefunken). **Center row**: La Radio Technique (R5 triode; G3 tetrode, 1924; R5 triode, later version; "GDER" [see Saga, p. 401]; unident. tetrode); Ediswan AR-06 triode, 1923; Philips AL5 spray-shielded power pentode; "Oxytron Radiøror" carton; Tungsram "Barium" KBC1 duo-diode-triode; Oxytron carton; three unident. (possibly Telefunken). **Bottom row**: RCA A-5661 UHF balanced mixer, 1941 (see *OTB*, Feb. 1993, p. 39); Marconi-Osram D.E.3 triode, 1924; Marconi-Osram DEV triode, 1922; Osram "R"; Loewe LA77 triode, 1924; Klangfilm full-wave rectifier and output triode; Telefunken RGN 2004 rectifier; Federal 8002R 2-kW air-cooled triode, 1940; two unident.

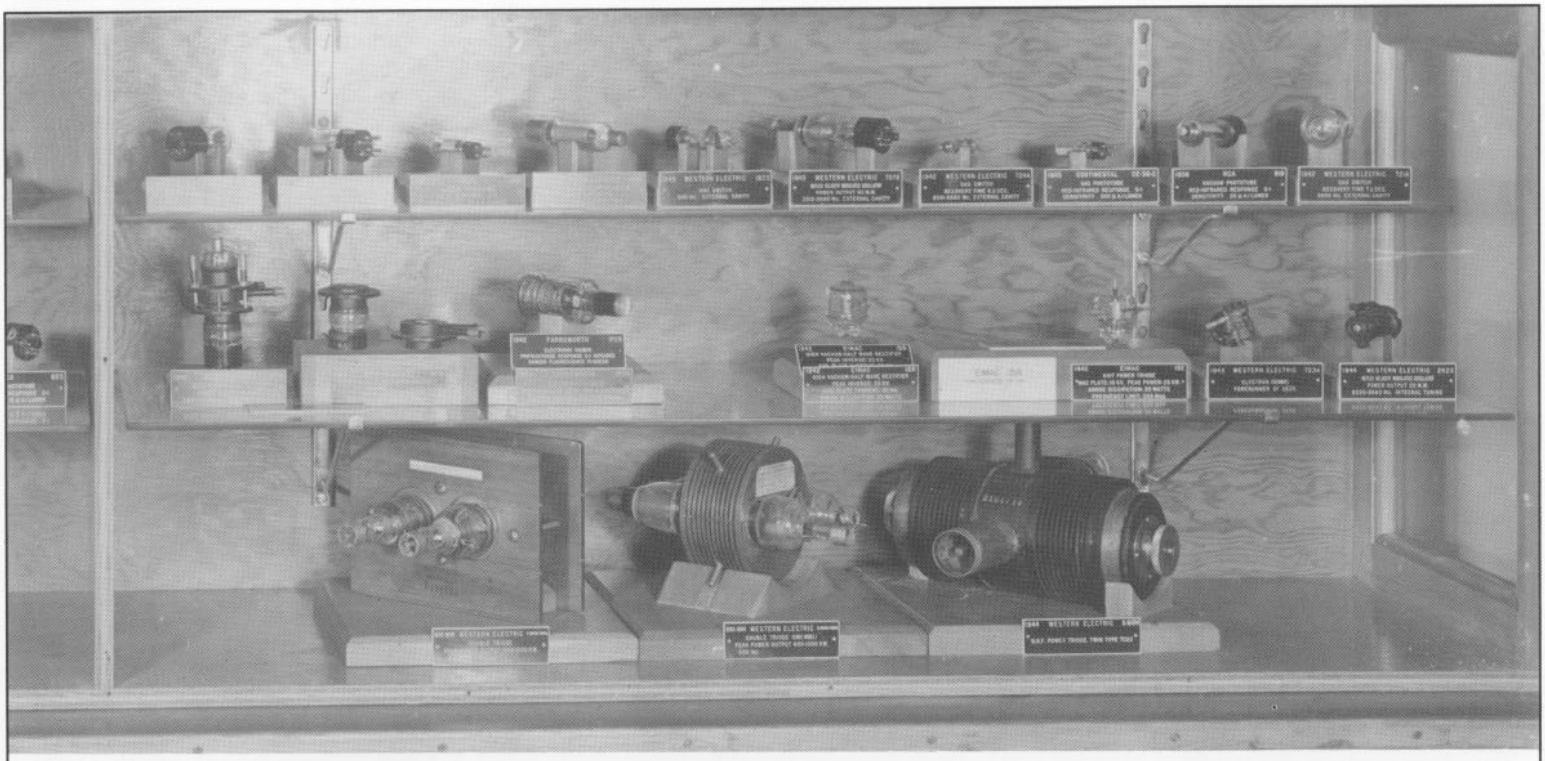


Photo and radar tubes. Top row: photocells (Continental 930, RCA 923, RCA 1645); Western Electric 1B22 radar-modulator switch, WE 1B23 T-R tube; WE 707B klystron, WE 724A T-R tube, Continental CE-36-C phototube; RCA 919 phototube; WE 721A T-R tube. Center row: Westinghouse 417A klystrons (whole and opened up); Farnsworth 1P25 night-vision device; Eimac 15R HV rectifier; Eimac 15E UHF power triode; WE 723A and 2K25 klystrons. Bottom row: WE dual VHF power triodes, of 1943-44 vintage, in the 600-1000 kW pulse class at 200 MHz: two versions of the D-166713, and the D-164714/7C22.

Magnetrons. **Top Row**: Split-anode CW UHF types, for use with external resonant lines: Federal 5J30, Federal 5J32, GE ZP-677, GE ZP-599, GE 5J29, GE ZP-676/5J33. **Bottom row**: CW and pulse types, including developmental: Raytheon 4J39, GE ZP-615 (mislabeled as Federal), GE ZP-636, GE ZP-xxx, Raytheon 4J33, GE ZP-597.

**ROYCE & MAREAN,**

DEALERS IN

**ELECTRICAL APPARATUS,**

Telegraph and Telephone Supplies,

No. 1408 Penna. Avenue,

Opp. Willard's Hotel, **WASHINGTON, D. C.**

Royce & Marean advertisement, 1885.

## SOME NESCO* NAVAL/MILITARY EQUIPMENT

Portable spark transmitter for Navy shipboard use, 1908
CN-112 submarine receiver
CN-113/113A tuner-receiver
CN-208/SE-143 tuner, 100-1200 kHz, 1917 "Navy utility set"
CN-239/SE-95 tuner, 30-300 kHz
CN-1105 spark aircraft transmitter with wind-driven generator, 1917
SCR-45 crystal receiver, Cohen "static-coupled"
SCR-125 wavemeter
SE-899 tuner
SE-950 receiver and radio compass for Navy aircraft, 125-1000 kHz (tuner, regen. detector, two audio stages), 1918, "first standard naval aircraft set"
SE-1950 radio compass tuner, 125-1500 kHz, 1921
TAV landing-party transmitter and receiver, 1930 (CN-3311 transmitter, 2-4.5 MHz; CN-3313 receiver, 0.3-0.6 and 2-4.5 MHz; etc.), 1930

* Not to be confused with the National Electric Signaling Co. (of Pittsburgh and Brooklyn), which was effectively out of business before WW I.

CN-3311 transmitter and CN-3313 receiver

# A HISTORY OF THE NATIONAL ELECTRICAL SUPPLY CO.

**Edward B. Duvall, ex-3DW**

*Originally published in 1961 as AWA Monograph No. 2, reprinted, by permission, from the Vitro Electronics "Communicator." Expanded and brought forward to 1993 with the help of David Harry of Potomac Instruments, Inc.*

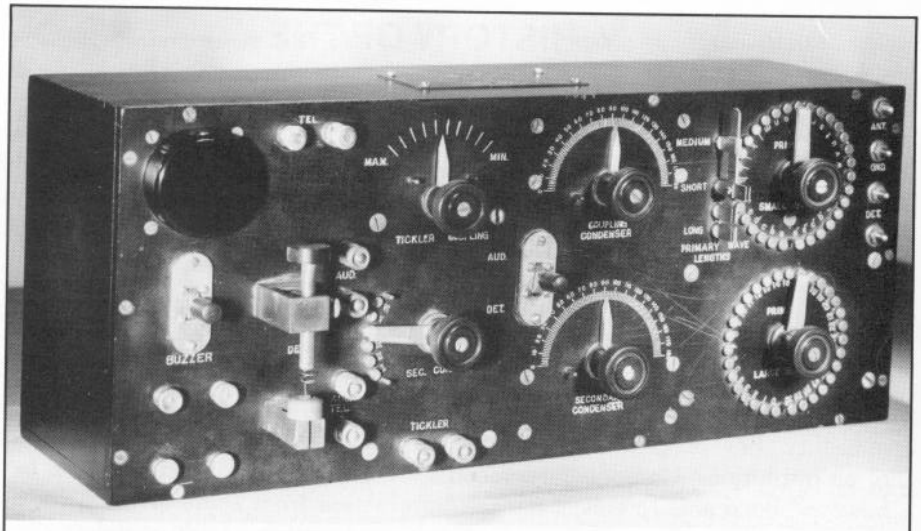
In preparing a history of this old Washington, D.C., firm, its very age presented two problems. First, the company goes back beyond the memory of any living member of the organization. Second, few people are vain enough to keep records of their businesses in the belief that someday others will want to use them in history. Few people, when starting a business, view their work as the founding of an institution. Consequently, records are often lost or destroyed. We have, however, been able to collect enough information from some of the older employees and from the surviving records to piece together a fairly complete record of the company's development.

Old ledgers in the company's archives show that a Mr. Fred Royce, who incidentally was an expert telegrapher for the War Department during the Civil War, joined with a Mr. Marean and established a machine shop on Water Street in old Georgetown, D. C., in 1880. Indications are that Mr. Marean also worked in the Government with Mr. Royce but had some business background. This company, then as Royce and Marean, specialized in brass and copper work, performed tugboat-engine repair, made shafts and propellers for small craft, and manufactured "electrical devices." By 1895 this company had moved to larger quarters at 1408 Pennsylvania Avenue, NW, in Washington. Active in both manufacture and sales, about this time it also organized the National Electrical Supply Company.

A few people were employed in constructing and installing electric doorbells (then quite a novelty) and lighters for gas illuminating fixtures. In this period the chief source of interior lighting was gas jets. In churches and assembly halls where the jets had to be installed in high places to throw light over the whole room, lighting them was quite a chore, as it required the use of ladders or long poles. The electric gas lighter which this company installed was a device for sparking these jets. Numerous buildings and churches in Washington were served by this device. However, an old ledger shows that the largest volume of business was probably in merchandising. Much of this electrical sales business was with the U. S. government, with the company acting as the local and government sales agents for such companies as Western Electric. Before and during the Spanish-American War, the company supplied the Army with telegraph instruments.

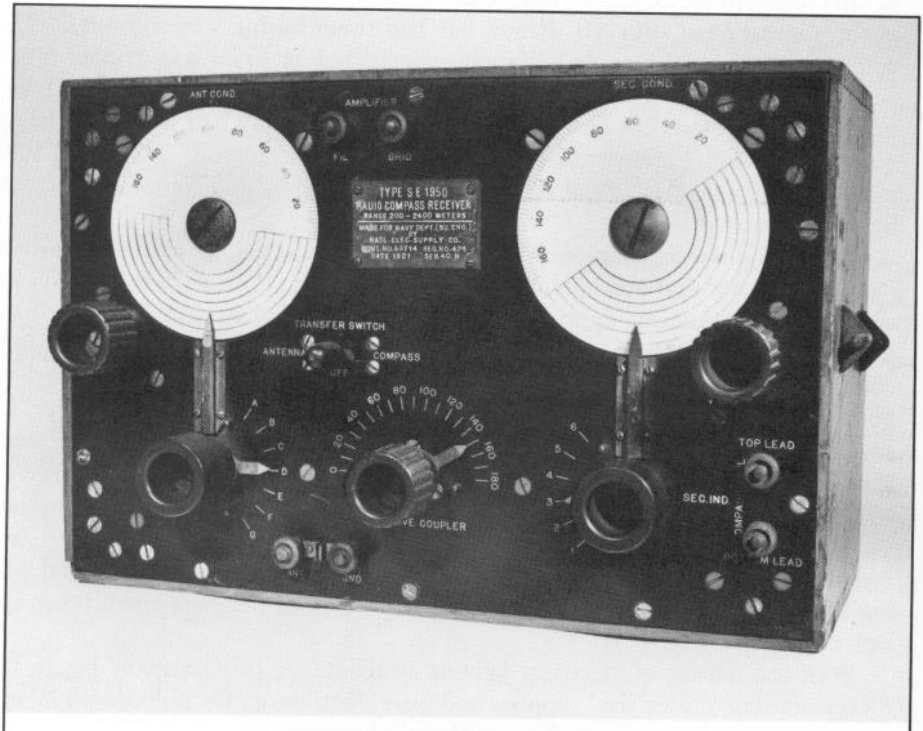
With the advent of electrical lighting installations, this company began the merchandising of electrical supplies and were distributors for all the well known manufacturers of wiring supplies and electrical appliances.

In the early 1900s, the U. S. government, both the Navy Department and the Signal Corps of the Army, called on NESCO for special pieces of electrical equipment. With the advent of wireless, some of the very first transmitting and




CN-113A tuner-receiver

*Photo: L. A. Peckham*




SE-1950 radio-compass receiver

*Photo: L. A. Peckham*

receiving instruments were built under contract for the government. Between 1909 and the beginning of World War I, this company built many of the instruments used by the Army, the Navy, and the Bureau of Standards, such as wavemeters, long-wave receivers, and small portable transmitters. When the war broke out in Europe, our military and naval leaders had to face the need for substantial quantities of radio equipment. Of necessity, this had to be based upon the relatively meager experimental developments which had taken place up to that time.

As this company had the experience of contributing to these developments, it was evident that the quantity of military equipment needed was far in excess of what could be produced in its existing factory. It opened a shop and moved the merchandising department to 1330 New York Avenue, NW. The company was then able to accept prime contracts and subcontract to a number of other firms. The company was particularly noted for producing "mobile" radio equipment ranging from pack sets carried on mule-back to complete transportable transmitting and receiving stations. This included supplying probably the first electrical generator ever put on a naval aircraft and some of the first radio equipment used on a submarine. Many of the long-wave receivers built by NESCO for naval stations, both ship and shore, can still be found in pretty good condition throughout the U. S. From 1915 through 1918 most of this receiving equipment was designed for use with crystal detectors. Some had provisions for connecting regenerative detectors using vacuum tubes and audion control boxes, providing some degree of amplification.

In 1917 one of the many contributions to the war effort was the manufacture of hundreds of a series of compact receivers for use on sub-chasers under the model numbers CN-113 and CN-113A. These were with and without detectors, with provisions for vacuum-tube operation, and were so designed that they could be used in landing-party pack sets, aircraft installations, and even observation balloons and outposts, where a light and portable battery-operated receiver was needed. NESCO was also doing special experimental model work for Major General Squier of the Signal Corps and Dr. Frederick A. Kolster. Many of the first Kolster decremeters were turned out at NESCO. In fact, this instrument was practically born in the testing laboratory and assembly shops of the company.

Naturally, NESCO could not bear the burden of building equipment to supply the government agencies by itself. Many of the other companies experienced in this type of material had to contract for many of the same designs and instruments in use at the time.

After the war, as the electric system in downtown Washington had originally us,ed mainly direct current, NESCO had a major part in converting hotels, theaters and public buildings from DC to AC. One of the larger jobs was converting the Veterans' Building. This task, one of the largest change-overs in the Distict of Columbia, involved replacing over 1000 electric motors. NESCO converted the Metropolitan and National Theaters, the Munsey Trust Company building, the Roosevelt Hotel, and many others.

The NESCO store at 1330 New York Avenue was a haven for commercial and amateur operators and enthusiasts during the early days of radio, when do-it-yourself projects were the order of the day and few complete radio receivers or

transmitters were on the market. Most of the sales force behind the counter were amateur operators or ex-commercial men, and a good many in the shop in the rear of the building were specialists in the field.

In the early Thirties, NESCO was a distributor for RCA Victor, the National Company, Hammarlund, and other amateur radio and commercial equipment manufacturers, besides continuing to supply commercial communication equipment to government and industry.

In 1937 the merchandising business of NESCO was sold to the General Electric Supply Company, a subsidiary of GE. The assets in the shop and factory were taken over by a few employees and several investors, who founded National Electrical Machine Shops Inc. This company was chartered as a corporation in the District of Columbia in March 1937, and moved to Fifth and V Streets, NE.

During World War II, the National Electrical Machine Shops, divorced from merchandising work, continued to do business with the government and various branches of the Armed Forces. Business expanded many fold as the entire facilities were devoted to this effort. For three years straight, NEMS won the coveted Navy "E" for excellence of performance. The company grew considerably in machinery and employees, but not in space, during these war years. At the end of the war it was quite apparent that NEMS needed room to grow, so in 1945 the company selected a site in Silver Spring, Maryland. The first floor of the plant was finished for occupancy in March of 1946. The company moved into its new home in April of that year to begin another era in its history.

Immediately after the war, Mr. Allan S. Clarke, W3AEV, who had been in the broadcasting field in Danville, Virginia, formed, with some associates, the Clarke Instrument Company to develop and market instruments for science and industry. The first items developed by this company were a series of field-intensity meters for AM-FM and telemetering bands. (Old-time broadcast engineers will remember making proofs of performance on directional AM antennas with the Nems-Clarke 120D or WX-2D field-intensity meter, which was distributed by Gates Radio and RCA.) He gave the job to NEMS to build them, and as Clarke had known the principals of NEMS for some time, he made arrangements to occupy some 5550 square feet of floor space in the new quarters. The field-intensity meters were followed by the development of phase monitors, telemetering receivers, and TV rebroadcasting receivers and accessories.

The company continued to grow with a reasonable degree of success, but when the Korean conflict started, it became increasingly evident to Mr. Clarke and the management of NEMS that the two companies complemented each other and that a merger would be beneficial to both parties. This merger was effected on January 1, 1951. NEMS became Nems-Clarke Company, Inc., with the quarters formerly occupied by the Clarke Instrument Company becoming the development and engineering laboratories. Mr. Clarke became vice president in charge of engineering. Mr. E. M. Nevils, Jr. was the first president.

The Korean war put such a stress of the production facilities that a second floor was added to the Silver Spring building and another building in the rear acquired in 1952. This operation was performed and completed without interruption to two-shift production. Employment reached an all-time high of over 500.

In 1954, after contributing to the success of the firm during its founding years, Mr. Nevils died and was succeeded by Mr. Clarke.

Besides government contracts and subcontracts with such firms as RCA and Bendix, many new proprietary products were added, including a series of special-purpose receivers for telemetering, professional electronic flash equipment, color TV rebroadcasting receivers, and special light sources for medical research and microphotography.

In 1957 another important change was made in the Nems-Clarke organization as it became an operating division of Vitro Corporation of America. Since 1955 this company had undergone a transition from predominantly contract manufacturing to engineering development and the manufacture of these developments. In 1960, the company was officially designated the Vitro Electronics Division of Vitro.

In the years since, numerous corporate reorganizations have occurred. A variety of spin-offs occurred, carrying with them parts of the Nems-Clarke product line. Telemetry receivers went to Defense Electronics, Inc. Surveillance receivers went to Communications-Electronics, Inc., which is now a part of Watkins-Johnson. The broadcast products, for example, the AM field-intensity meter, went to a firm started in 1968, Potomac Instruments of Silver Spring, Maryland. PI updated the design and added a line of other products. Vitro itself underwent acquisition by Penn Central Industries, and has recently become a subsidiary of Tracor, Inc.

## CHRONOLOGY

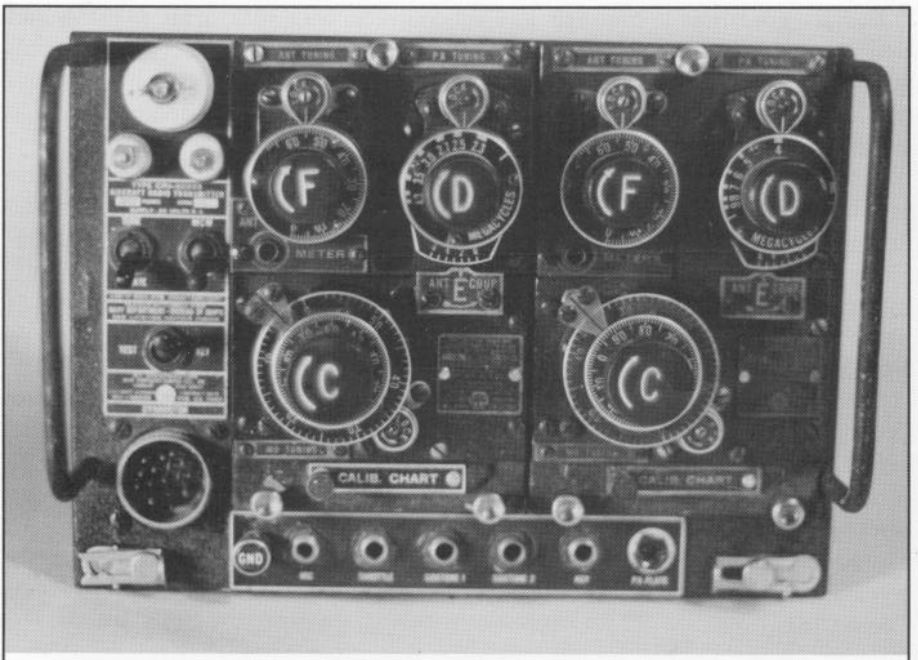
Royce and Marean, organized 1890
National Electrical Supply Company, Inc., organized 1899
National Electrical Machine Shops, Inc., organized 1937
Nems-Clarke Company, Inc., organized 1954
Vitro Electronics, organized 1960
Potomac Instruments, organized 1968, et al.

**Edward B. Duvall**

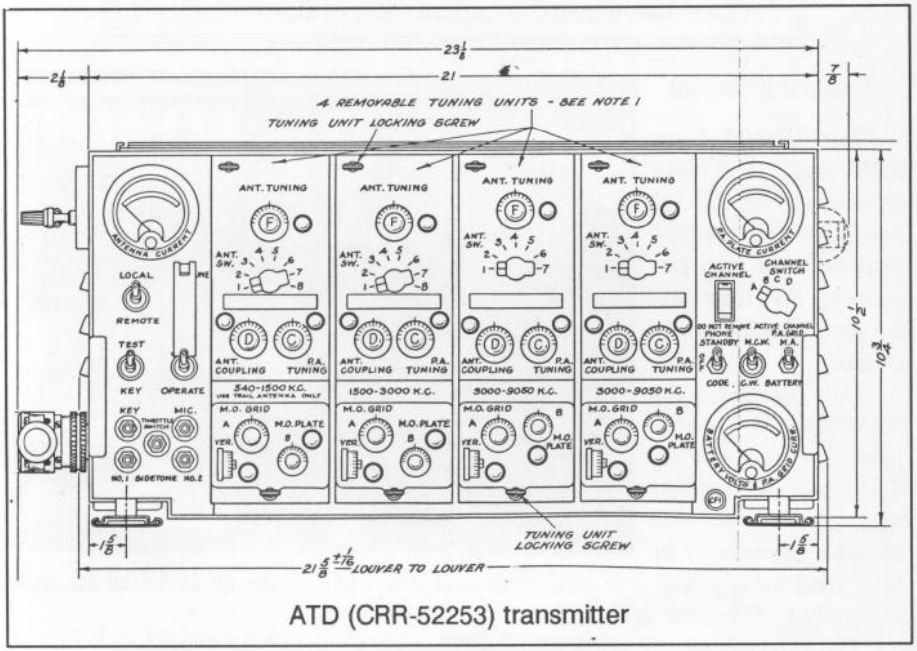
*Ted Duvall, ex-3DW and -3EM, was an early ARRL official and leader in amateur activities. He later became of the most active early amateur historians.*

*He worked for NESCO for many years. During WW II, Ted was associated with the Naval Research Laboratory. In later years he restored early radio gear and donated it to the U. S. Naval Museum. He died in 1975 at the age of 83.*

*The author is pictured with his CN-239 receiver.*




ATB (CRV-52223) transmitter




ATD (CRR-52253) transmitter

# NAVY ELECTRONICS DIRECTORY

**Frederick W. Chesson**
Waterbury, Connecticut

## NAVAL COMMUNICATIONS-ELECTRONICS EQUIPMENT

The following listing covers U. S. Navy electronic equipment from before World War I up to the introduction of the AN designation system.

The Navy did not follow the BC- and SCR- equipment nomenclature of the Army Signal Corps [1], but initiated its own system ca. 1915. Two-letter codes commencing with "C" were employed at first to identify commercial suppliers. CA, for example, designated equipment made by the American Radio Research Corp., while CF stood for de Forest Radio Telephone & Telegraph Co. These two-letter designations are mainly of the WW I period, but a few, representing such durable firms as CG (General Electric) and CW (Western Electric), saw use well past World War II. By mid-1943, the flood of new contractors was such that it became necessary to issue four-letter combinations [2].

There was a second, shorter-lived system. Since the Navy's Bureau of Steam Engineering had design responsibility for radio equipment, many sets of 1917-25 vintage were designated with SE-numbers.

Later ('20-'40s) and larger systems like radar sets employed alphabetic combinations, such as A(**) for aircraft equipment (e. g., the ABA IFF set, which also had the Signal Corps designation SCR-515), while B(*) was used for shipboard IFF equipment, D(**) covered direction-finding equipment, G(*) identified general aircraft transmitters, etc. Suffix numbers (or, occasionally letters) designated modified versions of the systems.

For components of these systems, five-digit numbers were assigned beginning with digit pairs representing particular "supply classes": 20xxx for power apparatus, 38xxx for vacuum tubes, 46xxx for receivers, 52xxx for transmitters, etc. In the case of radar and sonar equipment, the last three characters were usually letters. Prefixed with the manufacturer code, the resulting identifier might be "CNA-46080," the receiver portion (made by National) of the RAS-3 receiver system.

As common electronic equipment began to be used by both services, especially in aircraft, Joint Army-Navy, or AN/***, designations began to appear in 1943 and were in use for new equipment by the end of the war.

For reference, contract numbers (9xxxxx) are included in the listing where available.

## SOME VERY EARLY EQUIPMENT IDENTIFIED MAINLY BY MAKER

| | |
|---|---|
| **A** | Early receiver, 60-600 kHz, 1912 |
| **B** | Early receiver, 30-300 kHz, 1912 |
| **C** | Early receiver, 1.2-3.0 MHz, ca. 1913 |
| **K** | Arc transmitter, 2 kW |
| **Q** | Arc transmitter, 2 kW |
| **X** | Arc transmitter, 2 kW |

**CE-606A** Spark transmitter, 0.5-1.0 MHz, 0.5 kW, E. J. Simon Co., 1917
**CE-827** Spark transmitter, 0.315-1.0 MHz, 0.5 kW, ca. 1918
**CE-859** Spark transmitter, 0.315-1.0 MHz, 0.5 kW, 1917
**CE-861** Spark transmitter, 1 kW, ca. 1918
**CE-1221** Spark transmitter, 1 kW, 1918
**CL-304** Spark transmitter, 95-400 kHz, 10 kW, Fritz Lowenstein, 1917
**CL-342** Spark transmitter, 0.150-1.0 MHz, 2 kW, 1917
**CL-343** Spark transmitter, 95-400 kHz, 10 kW, 1917
**CL-344** Spark transmitter, 0.150-1.0 MHz, 2 kW, 1917
**CL-345** Spark transmitter, 0.150-1.0 MHz, 2 kW, 1917
**CM-296** Spark transmitter, 1.7-2.4 MHz, 0.5 kW, American Marconi, 1917
**CM-305** Spark transmitter, 0.15-1.0 MHz, 2 kW, 1917
**CM-306** Spark transmitter, 2 kW, 1917
**CM-307** Spark transmitter, 0.15-1.0 MHz, 2 kW, 1917
**CM-858** Spark transmitter, 0.095-1.0 MHz, 5 kW, ca. 1918
**CM-1080** Spark transmitter, 0.5-1.0 MHz, 2 kW, 1918
**CN-208** Receiver, National Electrical Supply Co., 0.1-1.2 MHz
**CR-654A** Spark transmitter, 0.315-1.0 MHz, 0.5 kW, Wireless Specialty, ca. 1918
**CR-655** Spark transmitter, 0.15-1.0 MHz, 2 kW, ca. 1918
**CR-1125** Spark transmitter, 0.095-1.0 MHz, 5 kW, 1918
**CT-1038** Arc transmitter, 20 kW, Federal Telegraph Co.
**CT-1042** Arc transmitter, 30 kW
**CT-1201** Arc transmitter, 20 kW

## LATER EQUIPMENT

### AB(*) - AIRCRAFT EQUIPMENT, IDENTIFICATION-FRIEND-OR-FOE (IFF)

**ABA** Mark IV IFF transponder, 470 & 493.5 MHz, Navy equivalent of SCR-515 (BC-645), 14/28 V, 1941. Uses dynamotor CWD-21AAX, equivalent to Army PE-103. Has same automatic self-destruction features as SCR-515. Able to be used in conjunction with ABK, to be identified by ground radars having either Mk III or MK IV IFF interrogators. Manufactured but not actually used - Mk III was chosen as standard system by U. S.-British agreement.

**ABD** IFF equipment, Philco/Raytheon, 38-52 and 195-220 MHz, CPR-46AAH, 1942

**ABE** IFF equipment, Philco/Raytheon, 100-116 and 175-225 MHz, CRP-43AAP, 1942

**ABF** IFF set

**ABK** Mk III IFF transponder, 157-187 MHz, like SCR-595C, made by Philco, Hazeltine, and Zenith, CZR-43AAY (24 V) and CHZ-43AAX (12 V), 900909, 1943. Uses British-style power and antenna connectors. Models through ABK-7.

### AI(*) - AIRCRAFT INTERCEPT RADAR EQUIPMENT

**AIA** First night-fighter radar, S-band, became AN/APS-6 ca. 1944

## AR(*) -AIRCRAFT RECEIVING EQUIPMENT

**ARA** Receiver, 0.19-9.1 and 9.1-13.5 MHz (CBY-46102 through -46107), like SCR-274N LF-MF-HF sets, 28 V, Aircraft Radio Corp. and Stromberg-Carlson.

**ARB** Receiver, 195-9150 kHz in 4 bands, AM-CW-MCW, 28 V, motor-operated bandswitch, RCA, 1941. Designed for application with the ATB transmitter but used mainly with others. IFs 135 kHz (bottom two bands; 915 kHz (top bands). 28 V, internal dynamotor. RCA commercial designation, AVR-50. Production 30,000. Main units are CRV-46151 receiver, CRV-23254 pilot's control box, CRV-23256 radio operator's control box, and CRV-23253 tuning head.

**ARE** Radio, 1942

**ARJ** Aircraft TV receiver, 264-312 MHz, 28 V.

**ARK** Aircraft TV receiver, 324-372 MHz, 28 V, ca. 1944

## AS(*) - AIRCRAFT SEARCH RADAR

**ASA** Radar, 400-MHz predecessor of ASB-series (not built), RCA, 28 V, 1941

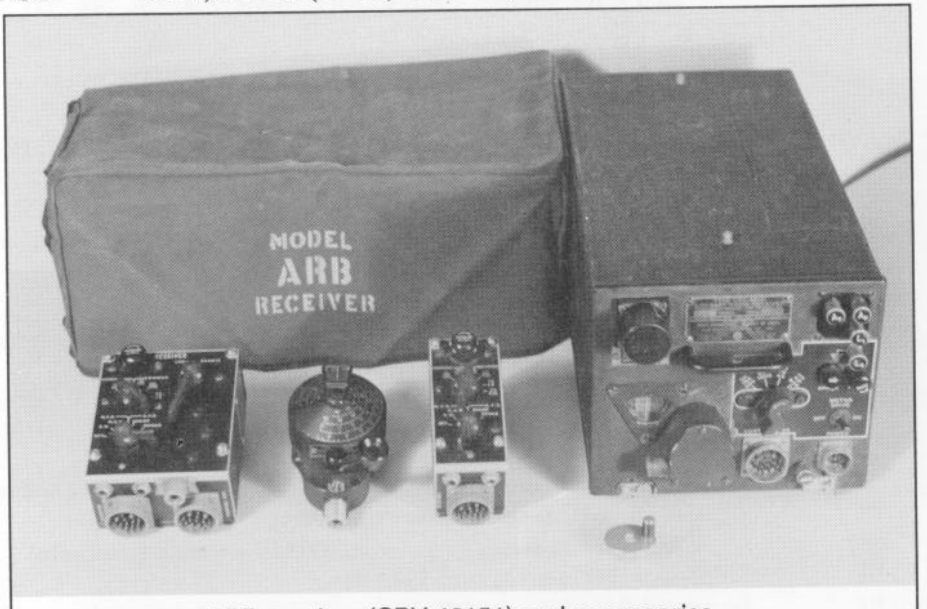
**ASB** First Navy airborne radar, 509-556 MHz, 1941 (receiver CPR-46ACJ or CAY-46AAM; indicator CQC-55ACB, transmitter CAY-52ABV or 52ACV), models to ASB-7 by 1944. Earliest receivers used acorn tubes in front end; later used lighthouse tubes. Began as XAT.

**ASC** Radar, S-band, WE, adapted from Army SCR-520, 1942-44.

**ASD** Radar (Sperry), later AN/APS-3, (Philco), 1943

**ASE** Early radar, based on British ASV, 176 MHz, Philco/WE, 1942

**ASG** Radar, S-Band (Philco), later AN/APS-2, 1942




ARB receiver (CRV-46151) and accessories
*Photos: Flemington Signal Depot*

**ASH** Radar, X-Band, later AN/APS-4, WE, 1943

### AT(*) - AIRCRAFT TRANSMITTING EQUIPMENT

**ATA** Transmitters, like SCR-274N HF transmitters but broader frequency range, 0.5 to 9.1 MHz in eight units (0.5-0.8, 0.8-1.3, 1.3-2.1, 2.1-3, 3-4, 4-5.3, 5.3-7, 7-9.1, designated CBY-52302 to -52305, -52232, and -52208 to -52211 respectively). 25 W CW, 12 W MCW, 8 W AM, 28 V. Aircraft Radio Corp. and Stromberg-Carlson.

**ATB** Transmitter, 2.3-9.05 MHz, 2 preset chans., 35 W AM-MCW, 55 W CW, 28 V, R/B ATC, U/W ARB, RCA identifier ATD-50, 1941, production 4000. Main units CRV-52233 transmitter, two CRV-47192 tuning units, CRV-21724 dynamotor, CRV-23314 pilot's control box, CRV-23313 operator's control box. About 3000 made.

**ATC** Transmitter, later redesignated T-47/ART-13, 0.2-1.5 and 2-18 MHz, 10 preset chans., 50 W AM or 100 W CW, Collins autotune, frequency-meter style VFO, 813 final and 811 modulators, COL-52286. Other units: COL-21932 28-V dynamotor, COL-21931 115-VDC dynamotor (!), COL-47281 antenna load coil, COL-48628 antenna shunt capacitor. Also see TCZ.

**ATD** Transmitter, 0.2-15.8 MHz, 50 W CW, 40 W AM, Bendix, 1940, 28 V, 814 final stage. Main components are CRR-52253 transmitter, CRR-55079 remote indicator, CRR-23280 remote control unit, CRR-21748 dynamotor, and CRR-47206 through 47211 tuning units.

**ATE-ATH** RCA, 28 V. Other details unavailable.

**ATJ** Aircraft TV transmitter, sends to ARJ, freqs. 276 and 312 MHz.

**ATK** Aircraft TV transmitter, sends to ARK, freqs. 264, 276, 288, 300, and 312 MHz, became T-61/AXT-2.

### AY - AIRCRAFT RADAR ALTIMETERS

**AYB** Altimeter, 420 MHz FM, 1 W, CRV-43016 (14 V) or CRV-43017 (28 V)

### B(*) - GENERAL SHIP & SHORE IFF EQUIPMENT

**BA, BE, BF, BG, BH, BI, BJ, BK, BL, BM, BO** Shipboard IFF interrogators, 1942-44

**BN** Shipboard IFF interrogator, 157-187 MHz, 117 VAC 60 Hz or, in some models, 400 Hz. Main components include:

| | |
|---|---|
| 10233 equipment cabinet | 50ACW duplexer |
| 10367 cabinet (modified) | 52ACQ transmitter oscillator |
| 43ACB mod. & IF-video conv. | 66ACG antenna |
| 46ACW IF converter | 66AFJ antenna (alternate) |

**BO** Shipboard IFF interrogator, 1942-44

**BP** Improved BN (different RF circuits: lighthouse tubes replacing 6J6s in the receiver; push-pull 15Es in the transmitter in place of a single 15E)

## CB(*), CC(*) - TEST EQUIPMENT

**CBL-1** Oscilloscope
**CBQ** VTVM, 900894; CBQ-3, 900945
**CCP** Sonar test equipment, 900878

## CX(**) - EXPERIMENTAL COMMERCIAL EQUIPMENT
(also see X[**])

**CXC** DF receiver, 2-25 MHz in 5 bands, CW-MCW-AM, CRV-46AAB with CRV-69AAA loop
**CXAJ** Receiver, 125-140 MHz, CW-MCW-AM, 12 V, GE
**CXAM** Later version of XAM radar, ca. 1939
**CXAS** See FA radar.
**CXAX** See WCA.
**CXAY** Sonar, CBM-78131, 40 kHz
**CXAZ** Fire-control radar, became Mk 5, 1942
**CXCH** See SO radar.
**CXDT** See SP radar.
**CXFG** Radar deception device, "Moonshine," 1943, became MBE.
**CXGE** Radar jammer, ca. 1943
**CXGL** Radar DF set, 91114
**CXGS** Radar DF set, 91022
**CXGU** S-Band echo-box test set, WE, 1943
**CXJW** Shore station transmitter, 91167
**CXKH** Radar DF set, 91021

## D(**) - DF AND LORAN NAVIGATION EQUIPMENT, RADIO & RADAR

**DA** Direction finder, modified SE-1440, 250-600 kHz, 1918
**DB** DF receiver, 45-600 kHz, 1922
**DK** DF receiver, 0.1-1.5 MHz, 1930
**DL, DM** DF receivers, 0.1-1.5 MHz, 1931
**DN** DF receiver, 0.1-1.5 MHz, 1942
**DO** DF set for submarines using CRV-69003 loop
**DP** DF receiver, 0.1-1.5 MHz, CRV-46136, 117 V, models through DP-14, 1934
**DQ** DF loop for RAK receiver, 1935
**DT** DF receiver, 2.5-30 MHz, 1936, originally XAB
**DU** DF loop, used with ARB and similar receivers, 0.2-1.5 MHz, 1938
**DV, DW** DF receivers, 0.2-1.5 MHz, 1938. DW-1, Bendix, 1940
**DX** Assembled DF equipment
**DY** Later model of DT, 1939
**DZ** Aircraft DF receiver, superhet, 0.015-1.5 MHz in 6 bands, 28 V with external dynamotor, uses loop with sense antenna, CRV-46152 (DZ-2), 1939, 3000 units made.
**DAE** DF receiver, superhet, 0.1-1.5 [or 0.24-2.0 in 3 bands] MHz, 175 kHz IF, 117 V, Radiomarine Co., CRM-46238, 900834, 1942, uses 14" loop with sense antenna.
**DAF** DF receiver, 0.1-1.5 MHz, Radiomarine, 1942

**DAG** DF receiver, 1.6-18.2 MHz in 3 bands, CIA-46174

**DAH** DF receiver, 0.1-1.5 MHz, Radiomarine, 117 V, 1942

**DAJ** DF receiver, 1.5-30 MHz (shore station), Federal CFT-46184, includes CFT-52365 test transmitter, 1942

**DAK** DF receiver, 0.1-1.5 MHz, 1942

**DAL, DAM** Related to DAJ-DAO (details unavailable)

**DAN** DF set, same receiver as DAJ, uses 4 goniometers and 4 sense coils depending on frequency

**DAO** DF receiver, related to DAJ (details unavailable)

**DAP** DF receiver, 0.1-1.5 MHz, 1942

**DAQ** DF receiver, 1.5-22 MHz (shipboard), crossed-loops type, 1942

**DAR** DF receiver, 1-20 MHz, 1942

**DAS-1** LORAN receiver-indicator, 1.7-2.075 and 9.9-12.1 MHz (basis of SCR-722, related to AN/APN-4), 900752, 1943; models through DAS-4, Fada Radio, 1945

**DAU** DF receiver, 1.5-22 MHz (like DAQ) with panoramic adapter, crossed-loops type, 1943

**DAV** DF paratrooper receiver, 2.3-4.5 MHz, Communications Co. Inc., 1943

**DAW** DF receiver, up to 30 MHz (mobile version), 1943

**DBA** DF receiver, 1.5-30 MHz, 1944

**DBB** DF set, 90-300 and 300-1000 MHz (may be based on RDO or AN/APR-1 components).

**DBE** LORAN set, 900659, 1944

**DBF** DF receiver, 100-156 MHz, 117 VAC, includes target transmitter covering 17.8-158 MHz in 3 bands, CW-MCW, battery-operated (probably MRD-8).

**DBN** DF receiver, ca. 1945

**DBS** LORAN receiver, 900306, 1944

**DBU** Submarine radar intercept receiver, 0.1-1.0 GHz, 1944. Began as XCV.

**DBV** Submarine radar intercept receiver, 2.0-3.5 GHz, 1944. Began as XCY.

### F(*) - GENERAL RADAR FIRE CONTROL EQUIPMENT (EARLY)

**FA** First fire-control radar (Mark 1), 700 MHz, 25-40 kW, 1940. Began as CXAS.

**FC** Mark 3 fire-control radar (improved FA), 40 kW, 1941

**FD** Mark 4 fire-control radar, 700 MHz, 40 kW, 1941

**FG** Radar, WE, early

**FH** Mark 8 fire-control radar, 3.0 GHz, 100 kW, 1942

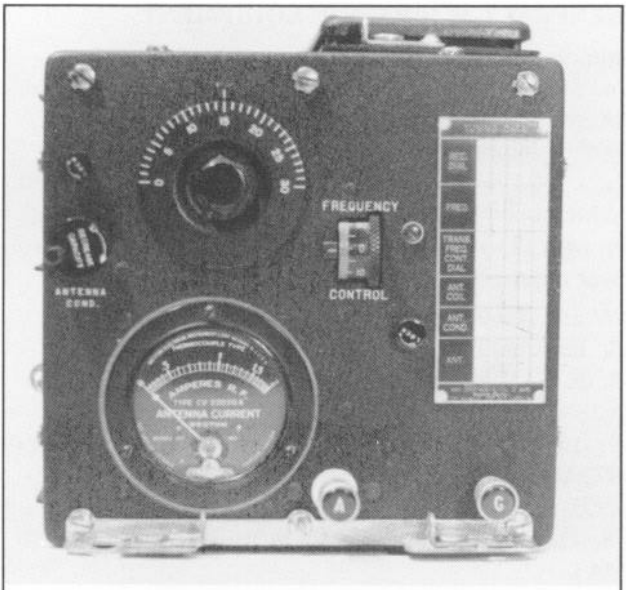
**FJ** Mark 9 conical-scan X-band radar, 30 kW, 1942

**FL** Mark 10 conical-scan X-Band radar, 30 kW, 1942

**FM** Mark 12, fire-control radar, 1943

### G(*) - GENERAL AIRCRAFT EQUIPMENT

**GF** Transmitter, 2.0-2.5, 3.0-4.525 and 6-9.05 MHz via five plug-in coilsets, 15 W AM-MCW-CW, 14 or 28 V, screen-modulated, used




GF-12 (CW-52063A) transmitter

with RU receiver, 1932-42. GF-11 model is WE CW-52063A, using CW-23097 control box. Typical radio combinations were GF-1/RU-3, GF-2/RU-3A, GF-3/RU-4A, GF-4/RU-5A, GF-8/RU-13, GF-11/RU-16, GF-11/RU-18, GF-12/-RU-17, and GF-12/-RU-19. Designer, and original maker, was Aircraft Radio Corporation; later WE. Original design was close to that of the Army BC-230 (SCR-183), but was given newer tubes in the late '30s: 837s in place of 801As, 89s in place of 45 Specials.

**GH** Transmitter, 4-13.575 MHz, 100 W, Westinghouse, ca. 1931

**GI** Transmitter, 4-13.575 MHz, 100 W, General Electric, ca. 1931

**GK-1** Receivers, CAY-46007, 0.015-1.0 MHz in 6 bands, and CAY-46009, 0.1-1.0 MHz in 3 bands.

**GL** Aircraft radio, 52-60 MHz, 1 W, AM, 1930

**GN** Transmitter, WE, 100 W, intended for use with RAM receiver.

**GO-9** Transmitter, 0.3-0.6 and 3.0-18.1 MHz, 70 W AM or 100 W CW, separate LF and HF transmitters using 803 final amps. powered by 117 V 800 Hz and 14/28 V, often used with RAX receiver. TBW is similar. WE design originally, later GE and Westinghouse.

**GP** Transmitters (through GP-7), 0.35-1.5 and 3-9.05 MHz, similar to TCE and shares tuners with it. WE design originally, later RCA and Westinghouse.

## J(*) - GENERAL SONAR RECEIVING EQUIPMENT

**JK** Sonobuoy hydrophone, supersonic, 13-37 kHz, related to WDA-1, ca. 1930.

**JM** First radio sonobuoy, for harbor defense, CIA-10090, 1941. Apparently transmits to RBF receiver.

**JP** Sonobuoy, hydrophone, ca. 5 kHz

**JR** Harbor-defense sonar, with 7 Rochelle-salts sensors

**JT** Sonar, RCA

**JAA** Receiver, 0.1-4 kHz

## L(*) - GENERAL CALIBRATION EQUIPMENT

**LD** Frequency meter, 0.1-5.0 MHz, GE, models through LD-3

**LF** Frequency meter, 30 kHz-30 MHz, for major bases, ca. 1928, includes xtal oven

**LG** Frequency meter, shipboard model of LF, ca. 1930

**LJ** Frequency meter, 0.195-1.5 and 3.0-13.575 MHz, 10 crystal channels.

**LM** Frequency meter mainly for aircraft, 0.125-20.0 MHz (0.195-20 before LM-10), with 125-kHz calibration crystal, 1934, models through LM-19. Power required:

LM: 14 V and 200-260 V
LM-1, -3: External batteries
LM-2, -4, -5: 14 V and 200-260 or 260-475 V
LM-4A: 28 V and 200-260 or 260-475 V
LM-7, -9, -10, -12, -14, -16, -19, -20: 14 or 28 V plus 200-260 or 260-475 V
LM-13, -17: 12 V and 180 V (internal batteries)
LM-6, -8, -11, -15, -18: 117 VAC (using rectifier 20120 or 20104A).

Units were CKB-74028 (LM-14, -15, -16, -17); CRR-74028 (LM-18 or -19). The feature of accepting 260-475 V plate feed was added for powering from the 475-V dynamotor of later GF-RU combinations. LM is similar in many ways to the Army BC-211, but has many design changes such as use of a voltage regulator and different mechanical layout. Makers: Bendix, Mission Bell.

**LO** Audio oscillator, beat-frequency type, replaced by LAJ

**LP** Signal generator, 9.5 kHz - 30 MHz AM-CW, Federal Mfg. and Eng. Co., models through LP-5

**LR** Frequency meter, heterodyne, 160 kHz - 15 MHz, 100-kHz calibrator with frequency dividers, 91136, models through LR-3

**LT** Test set for ABA IFF set

**LW** L-Band radar test set, 680-720 MHz, WE, includes signal generator and scope, CW-60AAL, 1943

**LX** Signal generator, 7.5-330 MHz AM-CW, Washington Institute of Technology, Inc. (appears to be a standard Ferris generator with external modulator-attenuator)

**LZ** Power meter, WE, 2.7-3.4 GHz, with antenna and detector.

**LAD** Signal generator

**LAE** Signal generator, 0.52-1.3 GHz, AM-CW-pulse, uses 2C40 tube, models through LAE-4, Airadio, Inc.

**LAF** Signal generator, 90-600 MHz, pulse, uses 2C40 tube, Frank Reiber, Inc.

**LAG** Signal generator, 1.2-4.0 GHz CW-FM-pulse, General Communications Co.

**LAJ** Audio oscillator, 20 Hz - 20 kHz, Triumph Mfg. Co., models through LAJ-2, appears to be repackaged HP 200A, replaces LO, 91143

**LAM** Frequency monitor, 1:10,000,000, RCA, later AN/FRM-3, 1946

## M(**) - GENERAL RADIO RECEIVING EQUIPMENT

**MD** Radio, 3-4 MHz, General Electric, 1927

**ME** Radio, 3-4 MHz, Westinghouse), 1927

**MK** Paratroop transceiver, repl. by MV through MX and then by MAB

**MM** Advance-base station, RBM receivers and TBW transmitters

**MO** Related to MAK; powered by 6-V vibrator supply, Communications Co. Inc.

**MQ** Transmitter-receiver, Radiomarine ET-8028, 2.0-3.5 MHz, 4 chans, 5 W, 6-V and 12-V models

**MU** Paratroop transceiver, 2300-2800 kHz (normally 2436 or 2772), xtal, 0.2 W AM (see MAB)

**MV** Paratroop transceiver 2800-3300 kHz (normally 3035 or 3135), xtal, 0.2 W AM (see MAB)

**MW** Paratroop transceiver 3300-3900 kHz (normally 3585, 3725, or 3865), xtal, 0.2 W AM (see MAB)

**MX** Paratroop transceiver 3900-4600 kHz (normally 3995, 4105, or 4435), xtal, 0.2 W AM (see MAB)

**MAB** Paratroop transceiver, 2300-4600 kHz, CCI-43085, replaced MU through MX. Includes CCI-43045 transceiver, dry batteries or CIA-20221 vibrator PS, CCI-66081 hand-held whip antenna unit. Circuit only loosely related to Army transceivers like BC-611 or BC-745.

**MAH** Receiver-transmitter, 140-144 MHz, 10 W AM, 4 channel, U/W TCS HF set. Uses DY-10/ARC-4 dynamotor; 12 or 24 VDC; rectifier available for AC operation.

**MAK** Transmitter-receiver, 3.0-8.0 MHz, MCW-AM, 25 W, 6/12 V, vibrator power supply, Communications Co. Inc.

**MAL** Mobile radio set, MAH and TCS, WECo

**MAM** Transmitter-receiver, 1.2-12 MHz in 3 bands, xtal or MO, 40 W CW-AM, COL-52357, powered by rotary converter, Air-Track/Collins.

**MAQ** Radio set, SCR-499-A, 2-18 MHz and SCR-542-A, 100-156 MHz

**MAR** Receiver-transmitter, 225-390 MHz, 43067, related to RDR

**MAS** Jammer set, like AN/ARQ-11

**MAW** Receiver-transmitter, 115-156 MHz AM, 0.75 W, 10 chans. Includes 43069 R-T. Transmitter part of 43069 is coded 52367.

**MAY** Receiver-transmitter, 225-390 MHz, 1 watt AM-MCW, backpack, CRP-43071, 6 V

**MBE** Radar deception device (gives impression of huge fleet), successor to CXFG "Moonshine," 1943

**MBF** Receiver-transmitter, 60-80 MHz AM, COL-43065

**MBL** VHF transceiver, 60-80 MHz, Collins

**MBN** Radio set

**MBO** Portable radio, 1.5-12 MHz, 10-25 W, AM-CW, 10 channels

**MBT** Radio set, 91115

**MBZ-2** Signal buzzer

**MHS-9** Head and chest set

**MRD-8** Alignment transmitter, 17-160 MHz, 52358, P/O DAZ DF equipment, probably same as Army BC-655.

## N(**) - GENERAL SONAR TRANSMITTING EQUIPMENT

| | |
|---|---|
| **NA** | Sonar beacon |
| **NG** | Sonar sender (Rochelle-salt transducer) |
| **NJ** | Lightweight echo sound recording equipment, 22.1-24.1 kHz (20.6 or 23.8 kHz, 60 W; or 21 kHz, 125 W). |
| **NK** | Portable echo sounding equipment, 6/12 V, models through NK-6 |
| **NM** | Magnetostriction echo sounding equipment, 17-19 kHz, models through NM-16A. NMA supplies 400 W. |
| **NGA** | Sonar system, 2 channels (20 and 67 kHz), 900662. NGA-1 system, 91048. |
| **NGB** | Sonar system, 91017 |
| **NMC** | Echo sounding equipment, 17-27 kHz, 12 W, RCA, 900443 |

## P(*) - GENERAL AUTOMATIC CODING RECEIVERS & TRANSMITTERS

**PD, PF, PG,**
**PH, PJ, PM**

## O(**) - GENERAL MEASURING, TEST AND TRAINING EQUIPMENT

| | |
|---|---|
| **OB** | Countermeasures modulation analyzer, 1944 |
| **OD-7** | Tube analyzer, transconductance, seven meters, sim. to Weston 686 |
| **OE** | VT voltmeters, multimeters, etc. |
| **OF** | Radar wavemeter & echo-box equipment |
| **OG** | Signal generator |
| **OJ** | AF impedance meter, 900994, models through OJ-3. |
| **OK** | Sonar computer |
| **OM** | Test monitor equipment |
| **OP** | Signal & sound-wave (audio) measuring equipment |
| **OQ-3** | Tube tester, transconductance, three meters, Weston 788, 1942 |
| **OR** | Underwater sound analyzing equipment, WE, CW-60019 |
| **OS** | Variously listed as oscilloscope, optical galvanometer recorder (GE), and fluxmeter |
| **OT** | Radar training equipment |
| **OU** | Training equipment |
| **OV** | Tube tester |
| **OW** | Sonar test equipment (OW-1 is listed as Air-Track Corp. code trainer) |
| **OX** | Radar trainer, Air-Track Corp. |
| **OZ** | Tube tester, transconductance, Hickok 550-X; also measures capacitance, resistance, and inductance. Models through OZ-2. |
| **OAA-2** | Frequency meter, radar, 150-240 MHz, AC-powered, 60ABC, measures freq. and relative power output. |
| **OAE** | Milliammeter |
| **OAF** | Frequency meter |
| **OAH-4** | Code-practice set, 91147 |
| **OAJ** | Radar echo box ("resonance chamber), CYT-14AAL, Yale & Towne |
| **OAK** | Standing-wave measuring equipment, slotted line, 3.3 GHz, 62ABD, Philco/Raytheon |

| | |
|---|---|
| **OAL** | Test equipment |
| **OAN** | Signal generator |
| **OAO** | Frequency meter, radar, 105-125 MHz, similar to OAA and OAF, 60ABA |
| **OAP** | Frequency meter, radar, 145-235 MHz (Hazeltine CHZ-60ABA or 60ACQ) |
| **OAS** | Sonar test set, including water target |
| **OAU** | Underwater practice target |
| **OAV** | Training equipment |
| **OAW** | Tube tester, portable, emission, General Communications Co. |
| **OAX** | Underwater sound generator (osc.-amp. and hydrophone), 17-26 kHz, 1 watt, Presto Recording Corp. |
| **OBC** | Variously listed as submarine hydrophone mount and as practice attack unit |
| **OBE** | RF oscillator, 40-200 kHz, 200 W, 117 V power, CG-35038 |
| **OBH** | Analyzer |
| **OBL** | Oscilloscope, 3", 100 kHz, models through OBL-3, Reiner Electronics Co. and Triumph Mfg. Co. |
| **OBO** | Recording microvoltmeter equipment, AC-powered chart recorder |
| **OBQ** | VTVM, Hickok, 900318, models through OBQ-4 |
| **OBT** | Oscilloscope, 3", DuMont and Reiner Electronics Co., 900296; OBT-1, 91126 |
| **OBU-4** | Radar echo box, 2.9-3.1 GHz, CW-14ABA |
| **OBZ** | Tube tester, emission, CBM-60097 |
| **OCD** | Pulse generator, 3000-6000 pps, General Communications Co. |
| **OCG** | Oscilloscope, 5", same as TS-324/U and DuMont 241 |
| **OCJ** | Radar target simulator |
| **OCK** | RF impedance bridge, 25 kHz - 5 MHz, measures R and C, Photoswitch, Inc. |
| **OCL** | Tube tester, 900807 |
| **OCP-1** | Sonar port testing equipment, 900811 |
| **OCR-1** | VOM, submersion-proof, Triumph Mfg. Co. |
| **OCT** | Frequency-shift monitor, 91131. Measures carrier freq. shift of FSK keyers. OCT-2 includes CHZ-60170 superhet receiver, 1-26 MHz. Models through OCT-3. |
| **OCV** | Research receiver (Stoddard NM-3), 100-400 MHz, 1944 |
| **OCW** | Insulation tester, 900726 |
| **OCY-1** | Radar DF target transmitter equip., 91011 |
| **OCZ** | Radar target simulator |
| **OKA** | Sound resolving equipment, 900791 |
| **OZI** | Tube tester, 900346 |

## Q(**) - SONAR LISTENING AND ECHO-RANGING EQUIPMENT

| | |
|---|---|
| **QB** | Sonar, ca. 1928 |
| **QC** | Sonar, 24 kHz modulated with 1.1 kHz |
| **QD** | Depth measuring equipment |
| **QF** | Sonar training equipment |

| | |
|---|---|
| **QG** | Sonar, console version of QC |
| **QJ** | Sonar, console version of QB |
| **QK** | Sonar crystal scanning equipment |
| **QL** | FM sonar equipment |
| **QX** | Auxiliary sonar echo ranging equipment |
| **QAA** | Portable sonar, 500 kHz, 0.5 W |
| **QBA** | Sonar equipment |
| **QBE** | Sonar equipment, 17.5-25 kHz, 900419, related to WEA-5 |
| **QBF** | Sonar, 22.5-25.5 kHz, 130 W, WE |
| **QBG** | Sonar equipment |
| **QBH-4** | Sonar scanning equipment, 10-50 kHz, 1953 |
| **QCD** | Sonar, harbor defense, 15-27 (21, 23, 25, or 27) kHz, Raytheon |
| **QCJ-2** | Sonar system, 900720 |
| **QCL** | Sonar system, RCA, 900720 |
| **QCN** | Sonar, Submarine Signal Co, 24 kHz |
| **QCQ-2** | Echo range equipment, RCA, 900805 |
| **QCR** | Sonar, Raytheon |
| **QCS** | Sonar, Raytheon |
| **QCT** | Sonar, Raytheon |
| **QCU** | Sonar system, 17-27 kHz, 10 W, RCA/Raytheon, 900740 |
| **QDA** | Sonar target depth equipment, 900700 |
| **QFE** | Sonar equipment |
| **QFG** | Countermeasures sound-effects generator, CRV-35028 |
| **QGA-1** | Sonar equipment, 13-37 kHz, Raytheon, 91253 |
| **QGB** | Sonar console, 17-26 kHz, 900805, RCA, ca. 1946 |
| **QHD** | Sonar, Raytheon |
| **QJA** | Sonar, 22-28 kHz, 130 W, WE |
| **QJB** | Sonar, 22-28 kHz, 130 W, WE |
| **QLA** | Sonar, 36-48 kHz, 250 W, WE |

## R(**) - GENERAL RADIO RECEIVING EQUIPMENT

| | |
|---|---|
| **RA** | Receiver, 16-1200 kHz, TRF, submarine use, 1921 |
| **RB** | Receiver, 10-50 kHz, TRF, shore-station use, 1920 |
| **RC** | Receiver, 50-2200 kHz, TRF, shore-station use, 1920 |
| **RD** | Receiver, 12-1200 kHz (for destroyers using two receivers), ca. 1921 |
| **RE** | Receiver, 10-100 kHz, multiplexed on a common antenna, 1924 |
| **RF** | Receiver, 75-1000 kHz, 1925 |
| **RG** | Receiver, first HF, 1-20 MHz, 1926 |
| **RH** | Receiver, 200-650 kHz |
| **RI** | Receiver, 40-1200 kHz |
| **RK** | Receiver, 12-375 kHz, TRF, 1926 |
| **RO** | Receiver, TRF, 0.015-25 MHz, CAY-3362, for S-Class submarines, 1928. RO-2, CAY-3940, TRF, 0.015-1.0 MHz, 1929 |
| **RQ** | Minesweeper receiver (CAY-3355), TRF, 0.015-1.0 & 1-22 MHz, 1929 |
| **RS** | Receiver, 3.75-22 MHz, shore-station use, ca. 1930 |
| **RT** | Receiver, 1-30 MHz, 1930 |

**RU** Receiver, TRF, 0.25-14.0 MHz in RU-1, later 0.195-13.575 MHz, via 13 plug-in coilsets, for fighter aircraft, 1931. Usually remote-controlled, often used with GF transmitter, models through RU-19, originally Aircraft Radio Corp., then Stromberg-Carlson and WE. Odd-numbered later variants use 28 V; even-numbered, 14 V. Coilsets are plain or switchable between two bands (e. g., 0.4-0.5 and 6-9.05 MHz). Typical receiver is CW-46048D or -46051A. Uses CW-23012 remote tuning head, CW-21441 dynamotor, CW-62017 junction box, and CW-23096A or -23087 switch box. Had same design origin as Army BC-229 (SCR-183), but evolved with detail improvements and updates of tubes (e. g., 39s to 78s).

**RAA** VLF-MF receiver, superhet, 10-1000 kHz, AC operated, RCA, 1931

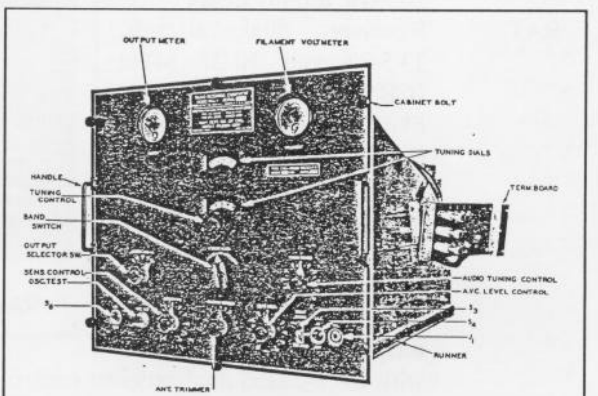
**RAB** HF receiver, superhet, 1-30 MHz, 1932

**RAC** Receiver, TRF, 12-80 kHz, shore-station use, RCA, 1931

**RAE** Receiver and tone keyer, 0.1-30 MHz, CRV-46018, 117 V

**RAF** Receiver, CG-46017, 117 V

**RAG** Receiver, TRF with separate heterodyne osc., 15-600 kHz, band-switched, CHS-46042, 1933. Uses CHS-20032 117-V power unit (or batteries) and CHS-23062 control unit.



RAG (CHS-46042) receiver

**RAH** Receiver, TRF with separate heterodyne osc., 0.6-23 MHz, CHS-46043, HF twin of RAG but with plug-in coils, ca. 1933. Uses same power and control units as RAG and CHS-47090 "inductance system" (storage box for the seven coil trays).

**RAJ** Receiver, 0.224-13.575 MHz, CW-MCW-AM, CRV-46046

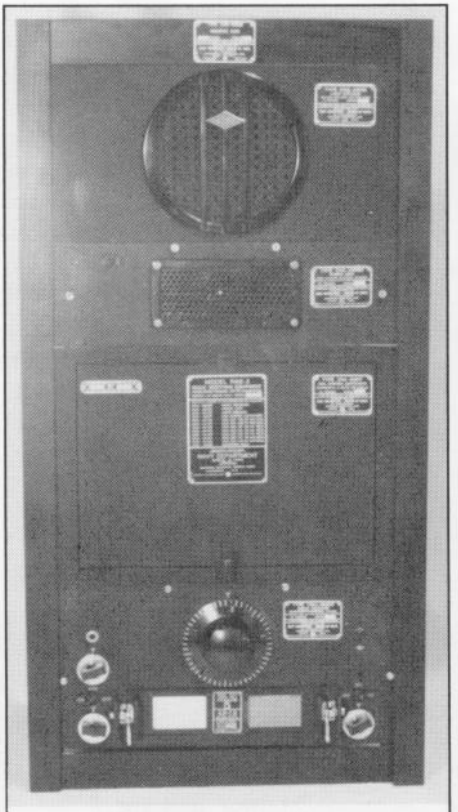
**RAK** Receiver, regen. TRF, 16-600 kHz in 6 bands, CRV- or CND-46155, 1939, 117 VAC (CRV-20131 external power supply) or batteries, includes switchable audio filters. Uses CRV-23073 control unit; usable with CRV-66096 submarine loop antenna. Models through RAK-8. Made by RCA and Andrea.

**RAL** Receiver, regen. TRF, 0.3-23 MHz in 9 bands, HF analog of RAK, CRV-46156, RCA et al., 1939, models through RAL-8.

**RAM** Aircraft receiver designed to work with GN transmitter, WE.

**RAO** Monitoring receiver, 0.54-30 MHz, National 120 (NC-100XA with two RF stages and no S-meter), 455 kHz IF, 117 VAC or batteries, some sets made by Wells-Gardner, 1944

**RAS** Receiver, 0.19-30 MHz, like National HRO Jr. but with 175-kHz IF, CNA-46080, 1939-43, models through RAS-5. Main components are CNA-46080 receiver, -20090 power unit, -49105 speaker unit, -10097 coil container, -47156 through -47162 coil-sets, and -10036 table rack. Could be fitted with CKB-50143 plug-in noise limiter. Despite manufacture by National, original 1939 contractor was General Electric Supply Corp.



RAS-3 (CNA-46080) receiver

**RAT** Receiver, dual, aircraft, 13.5-20 and 20-27 MHz (CBY-46083 and -45084), like a pair of ARAs in dual mounting, IFs 4.2 MHz on both, 14 VDC, 1939. RAT-1 uses 28 VDC with CBY-46108 and -46109 receivers. Both came equipped with CBY-23154 local-control adapter, but could be used with CBY-32155 dual-receiver control box for remote control.

**RAU-2** Radiosonde receiver & recorder, 900348, 1944

**RAW** Receiver, 0.175-30 MHz, like National HRO Jr. (big-pin tubes).

**RAX** Receiver, aircraft, General Electric and Air-Track. Three versions: 200-1500 kHz in 4 bands (CG-46115), 1.5-9 MHz in four bands (CG-46116), or 7-27 MHz in five bands (CG-46117), 28 V, IFs are 160, 915, or 2275 kHz; design sim. to SCR-274N with bandswitching. For local control only.

**RAY** Receiver, aircraft, 1943

**RAZ** Receiver, TRF, Radiomarine AR-8503, 15-600 kHz (originally 100-500), 117 V, 1939

**RBA** Receiver, shipboard, TRF, 15-600 kHz in 4 bands, improved RAA, 1941, used with CRB- or CRV-20130 rectifier; RBA-5, 91319; RBA-6, CFT-46300.

**RBB** Receiver, shipboard, superhet, 0.5-4.0 MHz in 4 bands, ca. 1940, used with CRV-20130 rectifier. RBB-2, 91319; RBB-3, 4, 91101. Made by RCA and Federal.

**RBC** Receiver, shipboard, superhet, 4.0-27 MHz, ca. 1940, like RBB except freq. range and 6AB7 first RF tube. Used with CRV-20130 rectifier. RBC-2A, 91290; RBC-3, 91319; RBC-3, 4, 91101. RBC-3A

had power unit for 400 Hz. Models through RBC-6.

**RBD** Receiver, CG-46132, 1.5-12 MHz, shares design aspects with RAX and BC-652.

**RBE** Receiver, diversity, 0.55-30 MHz, with loudspeaker, CG-46142, with single or dual preselector.

**RBF-3** Receiver, 70-90 MHz FM, rack-mounted, 117 V, apparently for reception from JM sonobuoy.

**RBG** Receiver, 0.54-31 MHz, 455 kHz IF, Hammarlund HQ-120, CHC-46140.

**RBH** Receiver, National NC-156 (CNA-46188) (NC-100A with two RF stages), 0.3-1.2 and 1.7-16 MHz in 5 bands, 1560-kHz IF, 117 VAC or battery power. 1943

**RBJ** Receiver, like National HRO Jr., big-pin tubes, 0.05-30 MHz

**RBK** Monitoring receiver, 27.8-143 MHz, CW-AM-FM, 117 V, CFT-46130, 1944. Possibly adapted from Hallicrafters S-36.

**RBL** Receiver, shipboard or shore-station, regen. TRF, 15-600 kHz in 6 bands, National, octal tubes. Similar in appearance to RAO or RBH. RBL-2, CNA-46161, 1942; RBL-3, Wells-Gardner; RBL-5, CNA-46161B. Powered by 117 V, external batteries, or CNA-20214 6-V vibrator pack. Designed to meet the Navy radiation limit of 400 picowatts.

**RBM** Receiver pair; RBM-2, CCT- or CAY-46076, 0.2-2 MHz in 4 bands, 140 kHz IF; and CCT- or CAY-46077, 2-20 MHz in 4 bands, 1255 kHz IF, ca. 1944. For powering a pair of sets, uses CAY-21837 dual dynamotor unit (12 V), CAY-20086A rectifier (117 V 60 Hz), or CCT-20085 rectifier (117 V 25 Hz). Housed in water-tight box which becomes the operating table. Possibly also made by WE.

RBM-2 (CAY-46077) receiver

**RBO** Shipboard morale receiver (CZC-46139 or -46225), 0.53-1.6 and 5.55-15.6 MHz AM only, low-radiation type, like Scott SLR-12, ca. 1942. Used with CRV-49131 power amplifiers for ship-wide loudspeaker distribution.

**RBP** Receiver, 3.0-24 MHz in 3 bands, with tone keyer for high speed (50 dots per second), 117 V, RCA

**RBQ** Receiver, 132-156 MHz, one xtal channel, U/W TDG xmtr in shore stations for point-to-point links, CW-46168, outdoor-mounted, apparently an adaptation of a civilian radio-relay system.

**RBS** Receiver, shipboard, 2.0-20 MHz in 4 bands, 455 kHz IF, 14 tubes,

117 VAC, separate amp.-power supply, Stromberg-Carlson

**RBT** Receiver, 27-280 MHz in 6 bands, AM, National (possibly adaptation of 1-10)

**RBU** Receiver

**RBW** Monitoring receiver, 1944

**RBX** Monitoring receiver, 1944

**RBY** Receiver

**RBZ** Receiver, 2-5.8 MHz, tunable personal set, receiver and battery box in canvas case on operator's chest, uses helmet as antenna (AC supply also made)

**RCE** Receiver, 2-30 MHz, like National HRO Jr., big-pin tubes, ca. 1942

**RCH** Receiver, shipboard or shore station, 80-560 kHz and 1.9-24 MHz, Scott SLR-F, CZC-46209, 117 VAC or 117 VDC via Scott Model 262 inverter. Also identified as AN/SRR-3.

**RCK** Receiver, 115-156 MHz, four xtal channels, for aircraft carriers and shore stations, Scott

**RCL** National, similar to NC-100.

**RCO** Receiver, 100-156 MHz, 1 chan., 117 V, Communications Company, Inc.

**RCP** Receiver, like National NC-100A

**RCX** Panoramic adapter, 1944

**RDC** Radar search receiver, 28.5-140 MHz in three bands, swept by motor, 5.25 MHz IF, 1944; RDC-A, 91289

**RDE** Receiver, 2.0-8.0 MHz in 4 bands, with plug-in tuner, Communications Company, Inc.

**RDF** Receiver, 0.2-0.5 MHz in 4 bands, AM-CW, with plug-in tuner, Communications Company, Inc

**RDG** Surveillance receiver, 0.5-30 MHz (modified HRO Jr. w/ sweep tuning and panoramic output), 117 V, 1944. Coilsets include CNA-47580, 0.54-0.9 MHz, -47581, 0.9-1.7, and -47411, 1.7-3.5.

**RDH** Surveillance receiver, 91074, 1944

**RDM** Receiver, triple diversity, fixed-station, 0.54-32 MHz, six bands, three RCA AR-88s (CRV-46246B), 91061, 1939

**RDO** Radar search receiver, 38-1000 MHz (3 plug-in tuning heads for 38-95, 74-320, and 300-1000 MHz), like AN/APR-4, CPR-46ABC, Raytheon, 12 V, or 6V and 250V supplied externally.

**RDP-A** Panoramic adapter, 91259

**RDR** Receiver, part of MAR UHF radio or usable by itself, 225-390 MHz, 10 xtal chans., 30.2 MHz IF, remote-controllable, 12 or 24 V, depending on model; or external power, 900841

**RDZ** Receiver, shipboard, 225-400 MHz, 15.5 MHz IF, manual tuning or 10-channel autotune, Collins and National, usually paired with TDZ, 1944, 150 lb.; RDZ-A, 91229. Began as XCS.

**REA** Receiver, 4.5-22 MHz SSB, fixed-station, triple diversity, independent sideand, WE Co. D-99945, works with TEF transmitter. Part of AN/FRC-10.

**REE** Receiver, 0.54-18.6 MHz in 4 bands, Scott SLRM, AC-DC version of RBO with BFO added, 1944

| | |
|---|---|
| **REJ** | Panoramic adapter, 91217 |
| **REK** | Receiver, 0.54-32 MHz in 6 bands, 117 V, CRV-46246 |
| **REN** | Sonobuoy receiver |
| **REZ** | Panoramic adapter |
| **RGU** | Aircraft and ground radio |
| **RUQ** | Receiver, 108-152 MHz, AM, single chan., Collins, ca. 1950 |
| **RVA** | Receiver, VHF fixed-tuned, Collins, 1950 |
| **RXA** | Multicoupler, 4.0-24 MHz, Mission Bell, 117 V |

## S(*) - GENERAL SEARCH-RADAR EQUIPMENT

| | |
|---|---|
| **SA** | Radar, first fleet type, 200 MHz, RCA, 1941 |
| **SC** | Radar, main fleet, 175-225 MHz, 1942; 100 kW (SC-1), 250 kW (SC-2, 3), 2 MW (SC-4); SC-6, 900860, 1942; SC-8, 91219; SC-12M, 91051 |
| **SD** | Radar, submarine search, 114 MHz, 149 kW, RCA, 1942. SDB model also. |
| **SE** | Radar, first Navy S-band search, for small vessels, WE, 1942 |
| **SF** | Radar, S-band (2965-3019 MHz), 80 kW, for PT boats and other small craft, Raytheon, ca. 1942 |
| **SG** | Radar, first fleet S-band, 50 kW, 1000 built 1942-43; SG-1 transmitter, 52ABE-1; receiver, 46ABD-3, SG-6, 900861, 1943, GE/Raytheon |
| **SH** | Radar, S-band search, WE, 1941 |
| **SJ** | Radar, submarine, S-band surface search and torpedo control (2965-3019 MHz), GE/WE, 1942. SJ-1 also known as Mk 27. |
| **SK** | Radar, improved fleet, 212.5-222.5 MHz, 1941; SK-1M, 175-225 MHz, 1 MW, GE |
| **SL** | Radar, 10-cm search (2720-2890 MHz), GE/WE, 1942. Variant: SLX (designed but not built; SL-1, 1943.. |
| **SM, SN** | Radars, shipboard, ca. 1943 |
| **SO** | Radar, 6275-6574 MHz, 250 kW, 2J27 magnetron, Raytheon, 1942; SO-1 and -8 receivers, 46ACA; SO-12M, 9.0-9.16 MHz, 91053 |
| **SP-1M** | Radar, mobile shore air-defense, 2700-2900 MHz, 700 kW, CG-46ADF, USMC version of Army SCR-584 |
| **SQ** | Radar, shipboard S-band, ca. 1943 |
| **SR** | Radar, fleet, 175-225 MHz (550-660 MHz for SR-2, 1244-1350 MHz for SR-3), 500 kW, 900946, 1944; SR-6A, 900989; SRA, 900946, RCA /WE/Westinghouse |
| **SS** | Radar, X-band submarine, surface search and torpedo control, developed from SJ, 1944; SS-1, 91281, SS-2, 1952 |
| **ST** | Radar, submarine, surface search and torpedo control, range-only, 8800 MHz, 85 kW, small antenna mounted on periscope, uses periscope tubing as waveguide, WE, 1944 |
| **SU** | Radar, X-band, Submarine Signal Co., 1944; SU-1, 1944 |
| **SV-1** | Radar, submarine aircraft-warning, S-band (3460-3760 MHz), 900825, WE/Raytheon, 1944-45; SV-3, 1950 |
| **SX** | Radar for fighter control, S-band (2780-2900 MHz, but height-finder subsystem uses 3500-3550), 1 MW, 1945; SX-1, 91177; GE/WE |

## T(**) - TUBE-TYPE RADIO TRANSMITTERS

**TA** Transmitter, 1.5-2.3 MHz, 5 W, ca. 1920

**TB** Transceiver, 0.6-1.0 MHz, 5 ch., 5 W CW, ca. 1920

**TC** Transmitter, 0.59-0.74 MHz, 5 ch., 150 W, AM-CW-MCW, GE, 1920

**TD** Transmitter, 0.1-0.6 MHz, 7 ch., 1500 W, AM-CW-MCW, GE, 1920

**TE** Transmitter, 0.3-0.6 MHz, 5 ch., 300 W, AM-CW-MCW, GE, 1920

**TF** Transmitter, 0.2-0.6 MHz, 7 ch., 300 W, AM-CW-MCW, GE, ca. 1921

**TG** Transmitter, 0.3-0.6 MHz, 5 ch., 300 W, AM-CW-MCW, GE, 1921

**TL** Transmitter, 0.2-0.6 MHz, 6.5 kW (former spark type), for battleships, 1922

**TM** Transmitter, 100 W, submarine use, ca. 1923

**TN** Transmitter, 6 kW, shore stations, 1923

**TO** Transmitter, 0.5-1.5 MHz, 100 W, battleship use, 1923

**TP** Transmitter, 75-600 kHz, 150 W, WE, 1923

**TU** Transmitter, 0.2-0.4 MHz, 2 kW, GE, 1923

**TV, TW, TX** Intrafleet transmitters, 2-3 MHz, 1925

**TAB** Transmitter, 0.1-0.555 MHz, CW-MCW, CAY-3438, models through TAB-4

**TAD** Transmitter

**TAF** Transmitter, 2-18 MHz, 1930

**TAJ** Transmitter, 0.3-0.6, 3-4.8, and 7.7-12 MHz, CW-MCW, 500 W, 900428, 1930, models through TAJ-19, RCA et al.

**TAO** Transmitter, 1930

**TAQ** Transmitter, 0.175-0.6 MHz, CW-MCW, 1 kW, 1930, models through TAQ-10

**TAR** Transmitter, 0.3-0.6 and 4.0-18.1 MHz in 3 bands, 200 W, xtal, 1929

**TAV** Beach-landing party transmitter-receiver, receives 0.3-0.6 and 2.0-4.525 MHz, sends 2.0-4.525 MHz, xtal calibrator, NESCO, 1930, 50 made; later models through TAV-2

**TAW** Transmitter, 15-34 kHz, 300 kW, GE

**TBA** Transmitter, 4.0-26 MHz CW, 1 kW, GE, powered by 440 V 3 phase, 900290, 1930, models through TBA-13

**TBB** Transmitter, 4.0-26 MHz, 6 chans., 1 kW, GE

**TBC** Transmitter, 4.0-26 MHz, 40-50 kW, GE, 230 V 3 phase power, 1930

**TBF** Transmitter, 2.0-4.525 MHz, 500 W, RCA, 1933; TBF-A is CAY-52008A, 2.0-18.1 MHz.

**TBG** Transmitter, like TAR, 1933; TBG-1, 91167

**TBH** Transmitter, RCA, 91118, 1933

**TBJ** Transmitter, 15-34 kHz, 500 kW, RCA, 1934

**TBK** Transmitter, shipboard including submarines, 2-18.1 MHz, 500 W CW-MCW-AM, 900388, ca. 1934, Westinghouse/RCA, models through TBK-20

**TBL** Transmitter, like TAR, 0.175-0.6 and 2.0-18.1 MHz, 200 W CW-MCW-AM, Westinghouse/RCA, 900373, 1935

**TBM** Transmitter, 2-18.1 MHz, 500 W CW, CAY-52169, used with CAY-

50065 modulator, WE also

**TBN** Transmitter, 0.2-2.0 MHz in 6 bands, 1 kW, CW-MCW, CAY-52046, 1934. TBN-3 covered 2.0-18.1 MHz in 2 bands, 500 W, CAY-52048

**TBO** Transmitter-receiver, sends 2.0-3.5 MHz, receives 2.0-8.0 MHz, hand-cranked or 12 V dynamotor, GE

**TBP** Transmitter, 28-65 MHz

**TBS** Receiver and transmitter, 60-80 MHz, 50 W AM-MCW, RCA, for intership voice use, 1938, models through TBS-8. Motor-generators were available for 120 VDC, 120 VAC, 230 VDC, 440 VAC.

**TBU** Transmitter, 0.3-2.0 MHz, 1 kW CW-MCW, CAY-52223, powered from 234 or 220/440 V, 900384, 1939

**TBW** Two-transmitter set, 0.35-1.0 & 3-18.1 MHz, 100 W CW, 25 W AM-MCW, U/W RBM in MM station. Similar to GO-9. Main components of TBW-3 are 20084 rectifier PS; 21648 motor generator, 60 Hz; 21652 motor generator, 25 Hz; 52238 HF transmitter for 12 V; 55239 LF transmitter for 117/234 VAC; 73004 gas engine generator.

**TBX** Receiver-transmitter, receives 2-8 (1515 kHz IF), transmits 2-5.8 MHz (2.0-4.525 in TBX-1 to -3), 9 W CW, 3 W AM, hand gen., uses external crystal calibrator, models through TBX-8. Components include 21263 hand generator and 43060 R-T unit. Receiver is powered by dry batteries; transmitter, by 12 V and 500 V. Set is comparable to Army SCR-694 (BC-1306) or RT-77/GRC-9. Models through TBX-7. GE/Hazeltine

**TBY** Receiver-transmitter, USMC portable, 28-80 MHz, 0.5 W AM-MCW, originally Westinghouse civilian model HR, 1941-43, uses dry-battery, wet-cell (with CAY-20144 vibrator pack), or AC power, models through TBY-8 made by Colonial et al. Uses electrically separate transmitter (push-pull 958As) and receiver (acorn-tube superregen with RF stage). Components include 21263B TBY-8 hand-cranked generator.

**TCE** Transmitter, 0.35-9.05 MHz, 125 W CW-MCW-AM; similar to GP and shares tuners with it. Westinghouse, CAY-52129.

**TCG** Transmitter, 50-150 kHz, 50 kW CW, GE

**TCJ** Transmitter, GE

**TCK** Transmitter, fixed-station, 2.0-18.1 MHz in six bands, xtal or VFO, 400 W CW or 100 W AM from parallel 813s. Requires external power unit. TCK-7, 900210

**TCL** Transmitter, 30-42 MHz

**TCM** Transmitter, 2.0-18.1 MHz, 125 W CW-MCW-AM, GE

**TCN** Transmitter, 0.3-2.0 MHz, 125 W CW-MCW-AM, GE

**TCO** Radiotelephone, Radiomarine, 2.0-3.5 MHz, 6 chans., 117 V, 900885, 1943

**TCP** Transmitter, 2.0-3.0 MHz, Radiomarine, 3 models: CRM-43009 32 V), CRM-43010 (117 VDC), CRM-43011 (117 VAC), 900868, 1943

**TCR** Radiotelephone, Radiomarine

**TCS** Transmitter and receiver, shipboard or portable, 1.5-12 MHz, 15 W AM, 25 W CW, 4 xtal chans. or tunable, 3 bands, 117 VAC PS, remote-controllable, Collins 18-Q transmitter & 51-Q receiver. Also

made by Capehart-Farnsworth. Components include:

| | |
|---|---|
| 20218 rectifier PS | 21827 motor-gen., 230 VDC |
| 20309 rectifier PS (alternate) | 21881 dynamotor, 12 V |
| 21100 motor-generator, 117 VDC | 23270 remote control |
| 21775 motor-generator, 32 VDC | 46159 receiver |
| 21776 motor-generator, 117 VDC | 47205 antenna loading coil |
| 21777 motor-generator, 117 VAC | 52245 transmitter |
| 21826 motor-generator, 24 VDC | 66040 whip antenna |
| MCH-34, 35, 36, USMC cases | |

Variants include TCS-2, as above, 12 V; TCS-5, 1.2-1.5 MHz; TCS-12 (the most common version); TCS-13, Hamilton, 1943

**TCU** Radio set, GE

**TCY** Transmitter, life-raft, 500 kHz, 5 W MCW, automatic "SOS" or hand keying, hand-cranked, like BC-778, Federal, 1943. Replaced by AN/CRT-3, which added alternating 500-8264 kHz operation.

**TCZ** Transmitter, 0.2-1.5 and 2-18 MHz, COL-52286A, appears to be same as ATC or T-47/ART-13 as equipped with the LF oscillator, 900854. Uses COL-23410 remote control, COL-47230 antenna loading coil, COL-47505 tuning unit (0.2-0.5 MHz), and COL-48628 antenna shunt capacitor.

**TDB** Transmitter, 2.0-22.1 MHz in 4 bands, xtal or MO, 200 W CW-MCW, Radiomarine

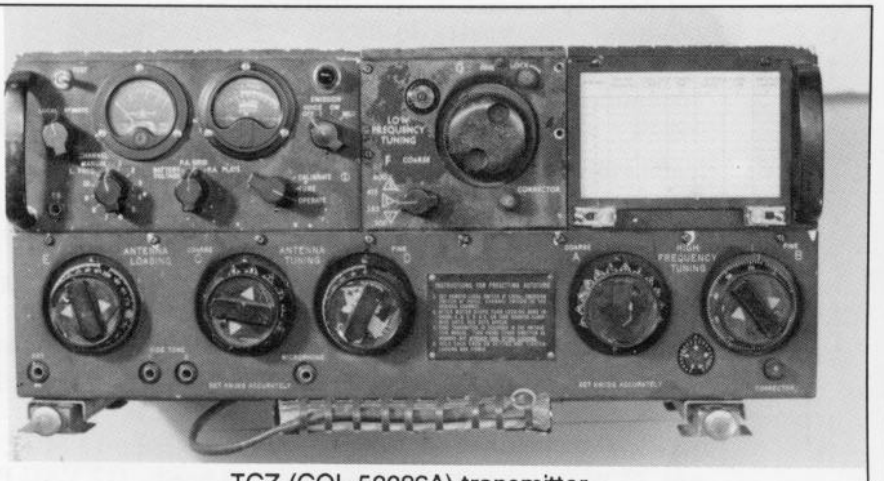
**TDD** Transmitter, 0.2-0.55 MHz, 15 W AM, 117 V, Communications Co., Inc.

**TDE** Transmitter, ship & shore, 0.3-18.1 MHz, 125 W CW, 35 W AM-MCW, CAY-52267, 900887, 1942

**TDF** Radiotelephone, 2.0-9.4 MHz, 6 xtal chans., 125 W CW-MCW-AM, Radiomarine and Raytheon

**TDG** 132-156 MHz, 12 W, CW-52366, U/W RBQ

**TDH-4** Transmitter, 2.0-18.1 MHz, 11 chans., MO, 3 kW CW-AM, COL-52291, TM 11-848, 1944




TCZ (COL-52286A) transmitter

| | |
|---|---|
| **TDJ** | Transmitter, Collins |
| **TDN** | Transmitter, 2.0-5.16 MHz (CIL-52294) or 13.0-20.0 (Press Wireless 52296), xtal, 3 kW CW, 117 V |
| **TDP** | LORAN-A navigation transmitter, 1.8 MHz, 100-kW pulses |
| **TDQ** | Transmitter, 115-156 MHz, 45 W AM, 4-chan., 900474, used with RBQ in shore stations for point-to-point links, RCA, 1944 |
| **TDR** | Transmitter, 225-400 MHz, 10 chan., 25 W AM, CG-52336, 117 V |
| **TDU** | Transmitter, 0.3-2.0 MHz in 7 bands, 1 kW CW-MCW, CAY-52123 |
| **TDY** | Radar jammer, 116-770 MHz (later 170-1250), 150 W, CG-35ABC and -35ABL, using dipole antenna, 1944. TDY-A, CRP-35ABV, covers 2700-3300 MHz, 150 W, using horn antenna |
| **TDZ** | Transmitter, 225-400 MHz, 10 xtal chans., remote-controlled, 30 W AM, paired with RDZ, 900809, RCA and Capehart-Farnsworth, 1944; TDZ-A, 91284 |
| **TEA** | Radar jammer, 15-54.5 and 40-120 MHz, 2 kW, CAY-50AFD, 1944 |
| **TED** | Transmitter, 225-400 MHz, xtal, 15 W AM-MCW, CAY-52373B |
| **TEF** | Transmitter, 4.5-22 MHz, six preset chans., ca. 2.5 kW, independent-sideband, fixed-station, WE D-156000, operates with REA receiver. A component of AN/FRC-10. |
| **TEG** | Transmitter, ship or shore, 0.2-18.1 MHz, 100 W, CRV-52372 |
| **TEH** | Transmitter, 1.7-2.0 MHz, 4 xtal chns., 1 kW CW, GE, 234 V |
| **THV-1** | Transmitter, HF, Bunnell, 1945 |
| **TLC** | Transmitter, LF, CW, Bunnell, 1942 |
| **TLG** | Transmitter, LF, AM, Bunnell, 1947 |
| **TPA** | RF amplifier, 4.0-22 MHz, 50 kW |

## U(*) - GENERAL REMOTE CONTROL EQUIPMENT

| | |
|---|---|
| **UA** | Carrier telegraph system, 5 chans, RCA |
| **UE** | Transmitter, LORAN, 1.7-2.0 MHz, GE, including CG-16239 receiver, 1943 |
| **UF** | Radio set control, SR-T equipment, 91070 |
| **UG** | Line terminal equipment U/W AN/MSC-2, WE |
| **UH** | Radio set control |
| **UM** | Transmitter, LORAN, GE |
| **UN** | Carrier telephone system, WE H1 single-channel, for open wire, 91261 |
| **UO** | Ciphony privacy system, CW-50293 et al. |
| **UP** | Carrier telegraph system, 12 chans., standard tones (425-2295 Hz), WE |
| **UX** | Mobile remote control equipment |

## V(*) - VISUAL RADAR PPI REPEATING EQUIPMENT

| | |
|---|---|
| **VC to VP** | Plan Position Indicator radar displays, later AN/SPA-4, 1943-44 |
| **VD-2** | Radar display, 900933 |
| **VE** | Radar display |
| **VF** | Radar display, Raytheon, 900858 |
| **VG-1** | Radar repeater display, 91316 |

| | |
|---|---|
| **VH** | Radar display, 900934 |
| **VJ** | Radar display, Raytheon |
| **VK** | Radar repeater display, 900986; VK-2, 91300 |
| **VL** | Radar display, 91075 |
| **VP** | Also listed as audio oscillator, 30 Hz-15 kHz, 1 mW, CW-30585 |

## W(*) - GENERAL SONAR RANGING-SOUNDING EQUIPMENT

| | |
|---|---|
| **WA** | Combined Rochelle-salt (R-S) and magnetostriction equipment |
| **WB** | Combined Rochelle-salt equipment |
| **WC, WD** | Combined Rochelle-salt and magnetostriction equipment |
| **WE** | Combined lightweight magnetostriction echo-ranging equipment |
| **WF** | Combined ranging-sound sonic equipment |
| **WCA-2** | Sonar, mine detector, 13-37 kHz, ex-CXAX, COL-23521 |
| **WDA-1** | Sonar, 13-37 kHz, Raytheon |
| **WEA** | Sonar, 17.5-25 kHz, Raytheon |
| **WFA-1** | Sonar equipment 91286 |

## X(***) - GENERAL EXPERIMENTAL EQUIPMENT OF NAVY DESIGN

| | |
|---|---|
| **XA** | Transmitter, first xtal-controlled high-power fleet, 4-8-12 MHz, 500 W, 1925 |
| **XB** | AC-powered version of XA for USMC, 1926 |
| **XC** | Transmitter, 2.0-4.525 MHz, 1926 |
| **XD** | Transmitter, shore-based high-power, 4-18 MHz ("Cornet"), 1926-27 |
| **XE** | Transmitter, first submarine HF, 2-18 MHz, 750 W, screen-grid tube, 1928 |
| **XF** | Transmitter, shore-station, 4-18 MHz, 5 kW, xtal, 1927; XF-1, shipboard version, 1929 |
| **XJ-1** | Receiver, early VHF, 4-50 MHz, first use of shield-grid tube, 1929; XJ-2, 14-75 MHz, 1929 |
| **XK** | Transmitter, for smaller submarines, 4-20 MHz, 75 W, xtal, 1929 |
| **XM** | Receiver, DF, 0.075-1.0 MHz, 1928 |
| **XP** | Transmitter, early VHF, 14-75 MHz, 500 W, 1929 |
| **XT** | Radio, aircraft VHF, 52-60 MHz, 1930 |
| **XU** | Monitor unit, 12-2500 meters, 1932 |
| **XV** | Receiver, VHF, 42-100 MHz super-regen, 1932 |
| **XZ** | Antenna diplex coupler |
| **XAB** | Receiver, DF, 2.5-30 MHz, became DT, 1936 |
| **XAE** | IFF system, early, 1939 |
| **XAF** | Radar, first fleet, 200 MHz, 15 kW, 1938 |
| **XAR** | Improved XAF, with anti-jam features, 1941 |
| **XARD** | Receiver, aircraft radar countermeasures, 1942 |
| **XAT** | Radar, aircraft, early ASB, ca. 1942 |
| **XBF** | Radar, shipboard search, 200 MHz, 500 kW, 1943 |
| **XBK** | Spot jammer, early, 560-620 MHz, 1943 |
| **XCA** | Spot jammer, early, 560-620 MHz, 1944 |
| **XCJ** | Transmitter, missile countermeasures, 1944 |
| **XCS** | Receiver, early version of RDZ, 1944 |

**XCU** Radio, early version of ARC-19, 225-400 MHz, 4 W AM, 1944
**XCV** Receiver, early version of DBU submarine radar-intercept set, 1944
**XCY** Receiver, intercept-DF, submarine, 2.0-3.50 MHz (see DBV), 1944
**XEV-1** Demux equipment, 91294
**XDM** Transmitter, submarine rescue buoy SOS, 1947
**XDAX** Transmitter (CFT-52369), 1.5-22 MHz, 3 bands, 5 W CW-MCW, 12 V
**XRAQ** Antenna control unit

**Y(*) - GENERAL NAVIGATIONAL & LANDING EQUIPMENT (GROUND)**

**YD-1** Marker beacon, 75 MHz, Air-Track/Collins, powered by engine generator or rotary converter
**YE** Homing equipment for carrier aircraft, like ZB, 200-250 MHz, 50 W, CRV-52234, 1937
**YG** Homing beacon, for carrier-based planes, 241-251 MHz, used with ZB, AN/ARR-1, AN/ARR-2
**YH** Navigational radar beacon, ca. 1943
**YJ** Navigational radar beacon, 500-530 MHz (possibly to work with ASB), Hazeltine, ca. 1943
**YL** Homing equipment for landing craft, 246 MHz, 1942
**YN** Beacon for YL unit, 1942
**YR** Type-H beacon, 1020 Hz modulation, Air-Track, 900784, 1943

**Z(*) - GENERAL NAVIGATIONAL & LANDING EQUIPMENT (AIRBORNE)**

**ZA** Instrument landing system (glide-path and localizer), 90-98 MHz, 14/28 V, CDE-46120 receiver and CDE-20109 signal converter
**ZB** Homing adapter for carrier aircraft, using RF modulation (0.54-1.03 MHz) on 234-258 MHz carrier. Uses acorn tubes. ZB-3 is CW-69076. Redesignated AN/ARR-1, replaced by AN/ARR-2, 1937-44. Models through ZB-4.


## ACKNOWLEDGEMENTS

Much of this material was excerpted from a large composite file compiled by Ray Mote. Portions of it were augmented by inspection of Navy equipment in the AWA Museum Annex and the Flemington Signal Depot.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| AN/ARC-2 | Vol. 33 No. 1, p. 16 |
| AN/CPT-2 | Vol. 33 No. 1, p. 13 |
| AN/URT-22 | Vol. 33 No. 1, p. 21 |
| | Vol. 33 No. 3, p. 34 |
| ARB | Vol. 31 No. 2, pp. 43, 53 |
| | Vol. 32 No. 2, p. 31 |
| ATB | Vol. 32 No. 1, p. 18 |
| CG-1104A | Vol. 32 No. 2, p. 13 |
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| | Vol. 25 No. 1, p. 14 |
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| RCK | Vol. 33 No. 4, p. 15 |
| RDG | Vol. 32 No. 2, p. 46 |
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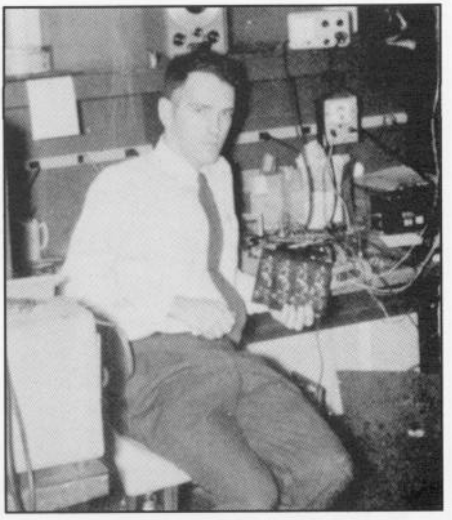
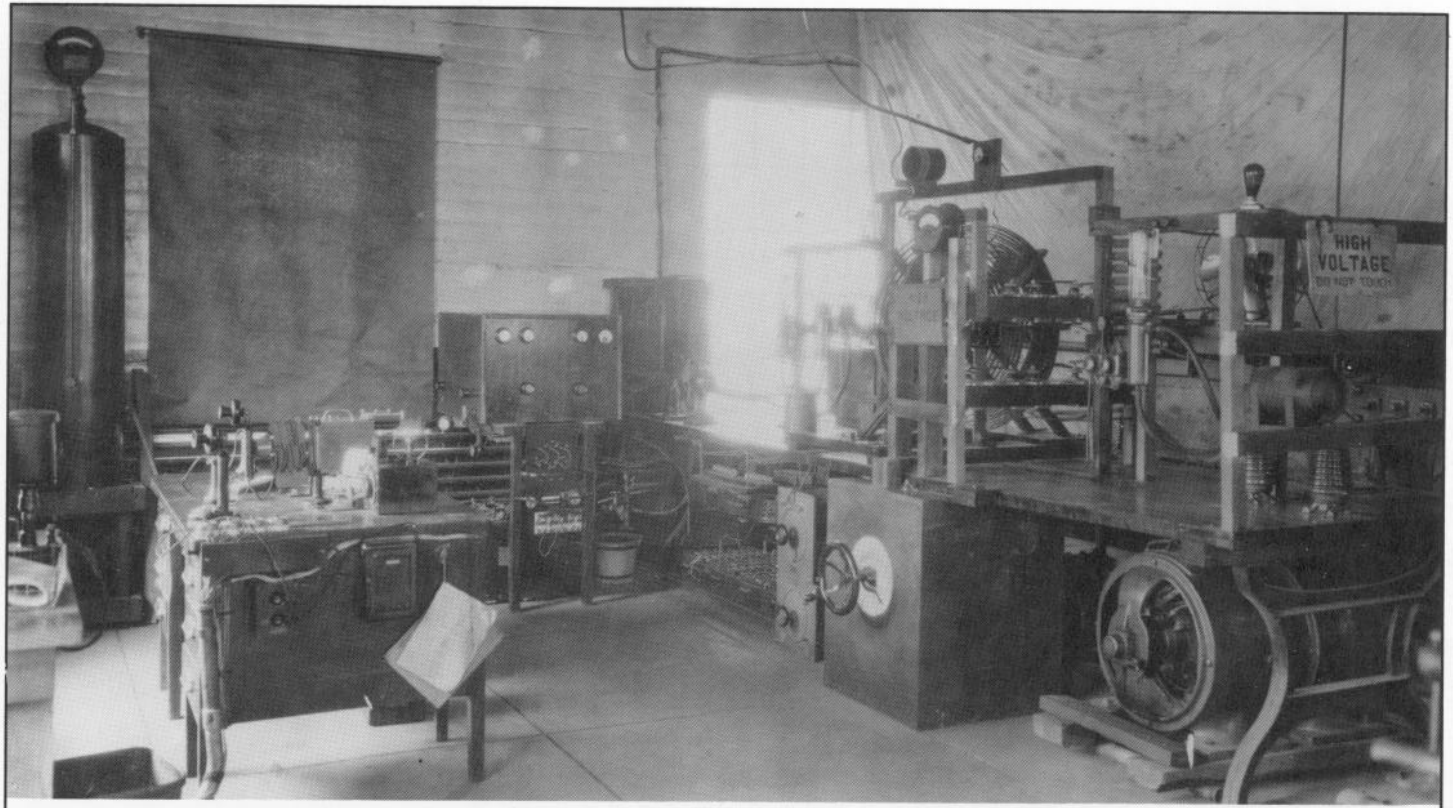
**Frederick W. Chesson**



*Fred Chesson came to the Electron Art when he was 16, via a Tesla-coil construction article in the January, 1946 issue of "Popular Science." The Tesla coil was duly built, using such diverse parts as a surplus VT-25, a UTC power transformer from the Heath Company, an oatmeal box, and the bakelite base of a (now highly desirable) Kennedy battery radio. Some 40 years later the coil came from the attic to take third place in an AWA equipment contest.*

*He graduated from the University of Connecticut in 1952 with a BA in Physics, then worked as an electronics engineer for about 20 years before gravitating into technical writing. His historical interest in Navy equipment goes back to younger days, when he made elaborate equipment lists from the exciting pages of "Radio News" and "Radio Craft." Acquiring a personal computer made a data base of this information possible.*

*When not involved in arcane antiquities like a definitive listing of all known Navy equipment, he does historical and travel articles, plus long-term research ranging from a study of Connecticut's war against tuberculosis, to Civil War ciphers and telegraph history, the lost iron industry, and various fiction projects.*




"Bench layout" at WGY. This transmitter dates from a few years before the 1930 tests, but gives the experimental flavor of the times. At middle right is a UV-207 triode, upright in its water jacket. The "pancake" tuning coil at center is wound of flat ribbon stock. On the floor are the usual motor-generator set for operating voltage and 12 or so storage batteries.

# A GLIMPSE AT OLD-TIME TRANSMITTER DEVELOPMENT

**Walter H. Nelson**

*The following report from 1930 was furnished by courtesy of AWA author John M. Anderson from the files of the Hall of History museum in Schenectady, New York. It gives insight into the difficulties of building a stable high-power (200-kW) broadcast transmitter with UV-862 water-cooled 100-kW triodes, which represented the tube technology available at the time. The photographs were not part of Nelson's memorandum, but are also from Hall of History resources. They illustrate the type of construction typical of transmitters of the time.*

## ENGINEERING MEMORANDUM - TRANSMITTERS

EMT #238

200 KW DEMONSTRATION OF WGY

RDA-961251

### SUMMARY

The development of the 200-kilowatt linear power amplifier was made possible by the evolution of an efficient process for the prevention of parasitic oscillations. Experiments were conducted without excitation on first one tube, then on two in parallel, and finally on three in parallel. The parasitics introduced by each change were studied as they occurred, and the process by which each was prevented is described in this paper.

The chief obstacle to successful parallel operation of UV-862 Radiotrons was the dynatron characteristic of most of the 862 grids, which characteristic engendered dynatron parasitics in the grid circuit which were difficult to control, inasmuch as they were practically independent of the plate circuit. Control was effected in this six-tube amplifier by three devices: (1) by partial compensation of the dynatron characteristic; (2) by a non-inductive low resistance in parallel with the grid tank; and (3) by use of a grid choke coil of special constants through which the grid bias voltage was fed, at the electrical center of the grid tank coil.

Dynatron compensation was accomplished by dissipating 3 kilowatts from the driver on the plates of biased kenotrons connected across the grid tank. The accompanying oscillograms were taken with two tubes in the last stage. They well illustrate the magnitude of the problem of controlling six tubes.

### INITIAL PROBLEMS IN PARALLELING VACUUM TUBES

The difficulties encountered in paralleling UV-862 Radiotrons were surmounted in March, 1930, when a 200-kilowatt carrier was first used in the broadcast spectrum.

A change from shunt feed to series feed was the first important step toward successful parallel operation, inasmuch as chokes and blocking condensers engendered parasitics.

Parasitics of three types were dealt with: (a) circuit parasitics, (b) inter-tube parasitics, and (c) dynatron parasitics.

Dynatron self-excitation of the grid tank was the hardest to control, and may constitute a limiting factor in the number of tubes which can be paralleled for class B operation. Obviously this same characteristic is very desirable in class C service, since a low-powered driver would be sufficient to saturate grids which draw positive grid current over but a small portion of the positive half-cycle.

In this discussion, circuit parasitics are distinguished from inter-tube parasitics by the circuit elements which fix their frequency. Thus circuit parasitics may involve the grid and plate chokes and blocking condensers, while inter-tube parasitics exist among tube elements and leads alone. Furthermore, all three types of parasitics occur both as push-pull and as parallel oscillations.

All of the above-mentioned parasitics can exist in a two-tube push-pull class-B amplifier under normal operating conditions without seriously interfering with regular use, the only indications of their presence being instability on high percentage modulation, and excessive radio-frequency voltage at the anodes of the tubes.

Parasitics may waste considerable power in a class-B amplifier. When parasitics were removed from the 50-kilowatt stage of W2XAG in August 1929, the plate current per tube dropped from 4 to 3.2 amperes, with no change in the antenna current.

All types of parasitics are enhanced when tubes are paralleled. An amplifier which may operate indifferently well with two tubes may be unusable with four tubes.

For close study of a parasitic, the plate voltage should be reduced, the excitation removed, and the bias reduced until plate current flows. If the spurious oscillation becomes too violent, it may be tempered by inserting a high resistance in the bias supply. It is well to have low-current fuses in the bias supply when experimenting with parasitics, as large grid currents may momentarily flow even with the high resistance in series with the bias. When the parasitic oscillation is sufficiently reduced in amplitude to be stable, its frequency may be determined at leisure with a frequency meter. The frequency will suggest the circuits from which the parasitic arises. Too close proximity to high-powered ultra-high frequency fields should be avoided, because of danger of excessive synthetic fever.

The following material applies particularly to push-pull amplifiers, but most is also applicable to single-ended stages, either class B or class C.

Connecting the grids together will determine whether the parasitic oscillation is push-pull or parallel. If the parasitic oscillation is unchanged with the grids tied together, the circuit involved is the well known tuned-grid tuned-plate circuit, the frequency-fixing elements being the grid choke coil with its distributed capacity working into the reactance of the plate chokes; or the grid choke in parallel with the grid tank condensers working into the tank formed by the plate choke in parallel with the plate blocking or plate tank condensers. In the latter case the frequency will obviously be much lower. Innumerable combinations of circuit elements are possible, as is evident from inspection of the circuit diagram.

Suppression of parasitics by resistors and small chokes is undesirable, as it invariably impairs the characteristics of the power amplifier, especially so in class B service.

## REMEDIAL MEASURES

Except for dynatron parasitics, in which only one tuned circuit is involved, the straight-forward remedy is always to detune one of the parasitic-controlling tanks; thus an ultra-high-frequency parasitic may yield to a one-inch change in the length of the leads to the neutralizing condensers, or by a similarly simple procedure.

The remedy in the parallel tuned-grid tuned-plate oscillation mentioned above is to reduce the size of the grid choke and feed in the bias at a point correspondingly nearer the electrical center of the grid tank coil, to preserve an accurate balance of excitation to both halves of the push-pull amplifier. The 50-kilowatt stage of W2XAG at So. Schenectady was operated for several months with no chokes whatever, the electrical centers of grid and plate tank coils having been accurately located. When quick change from 790 to 660 kc became a necessity, small chokes were introduced to facilitate the changeover.

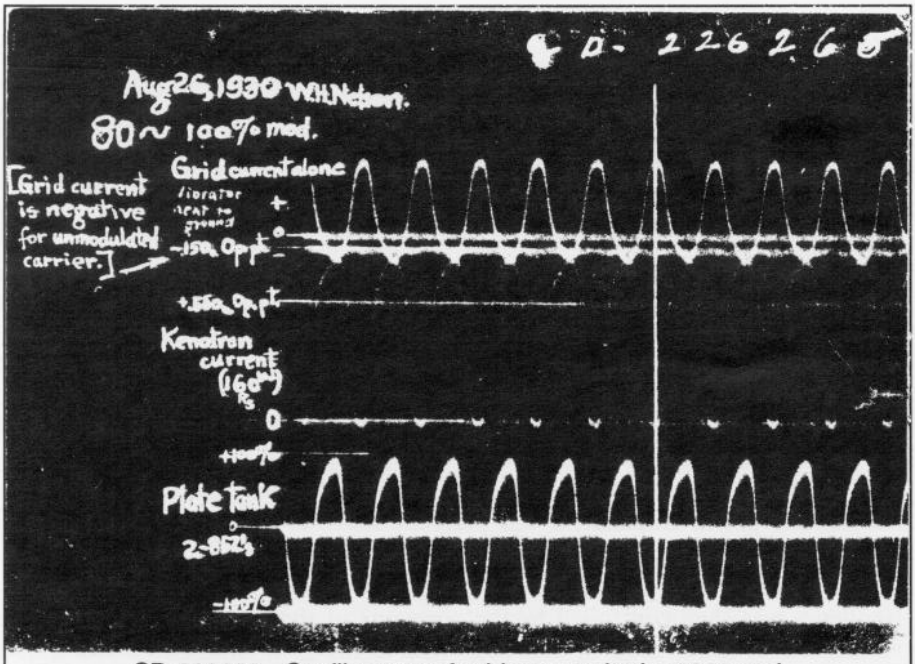
When all regenerative-type parasitics had been detuned and eliminated from the six-tube power amplifier, it was perfectly stable at any plate voltage as long as the grids were negative, but when half-saturation excitation was applied, it could be removed without materially changing the output of the amplifier. The frequency was then controlled by the constants of the grid tank, and could be varied over a wide range by shorting turns in the grid tank with a disconnect pole, the output of course decreasing with the amount the frequency differed from the fundamental of the antenna circuit. The dynatron-excited amplifier is rich in harmonics, the frequency meter responding to harmonics as high as the fifteenth. By reversing the bias and running the grids slightly positive, the amplifier was self-starting, indicating that the dynatron parasitics exist only during positive swings of the grid, but if strong enough will carry through the negative range when once started. Modulation was obviously impossible.

It was interesting to note that some measure of control was obtained when the neutralizing condensers were disconnected, about 40% negative modulation being possible with half-saturation excitation.

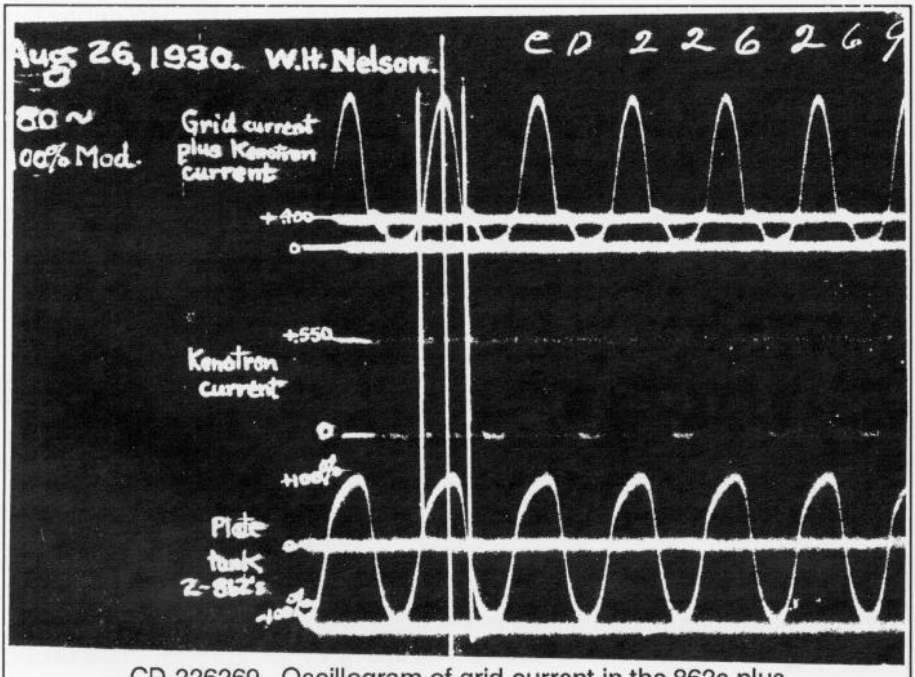
The accompanying oscillograms were made of the performance of the two UV-862s now in use at super-power (Aug. 1930), as no oscillograph was available at the time of the high-power tests. Of the six tubes used in the 200-kW demonstration, four had characteristics similar to the two now in use, and two showed negligible dynatron action. The use of the latter tubes along with the other tubes simplified the problem to the control of two grids in parallel, rather than three, thus greatly reducing the amount of dynatron compensation required for satisfactory stability.

The oscillograms were taken with 100% modulation at 80 cycles. The 30-ohm potentiometer inserted in series with the grid bias for the oscillograph vibrator disturbed the regulation of the bias circuit and cause the distortion of the plate wave on the positive halves. The "batting" of the grid current necessitated the use of a bias generator with a 3-ohm armature and a very stiff filter to prevent wobbling of the bias voltage during modulation.

The negative-resistance characteristic exhibited by the grids on these oscillograms is clearly an index of the shape of the radio-frequency grid-current wave, which must be extremely ragged, as the rich harmonic output of the grid tank




CD-226268. Oscillogram of grid current in the 862s and current in the kenotron damper diodes, vs. modulation.




CD-226269. Oscillogram of grid current in the 862s plus current in the kenotron damper diodes, vs. modulation.

when dynatron-excited shows. In a test with Sacandaga Receiving Station conducted without dynatron compensation on the present two tubes, it was found that slugs of high modulation broke over into adjacent channels, and that the channel invaded by peaks of modulation could be adjusted by varying the grid tank tuning, and by applying a small amount of dynatron compensation.

Dynatron compensation was accomplished by paralleling the grid tank with kenotrons, which draw positive current on the positive swings of the grid, during which swings the grids exhibit their negative resistance.

Dynatron control was effected in the six-tube 200-kW power amplifier by a combination of kenotrons and a grid choke of special constants. Three kilowatts were dissipated on the plates of four UV-651s in parallel with the grid tank. A grid choke highly capacitive at 790 kc proved very effective in increasing the control of dynatron parasitics. With the kenotrons alone, about 30% modulation was possible, while with the addition of the choke, 90% was used without noticeable distortion. Broadcast quality was departed from only on peaks of modulation above 90%, where a 20-cycle rattle impaired the quality. 20 cycles is the natural frequency of oscillation of the bias supply to the power amplifier, and heavy modulation swung the grids over to a point of steeper negative resistance where they excited the bias supply in spite of the heavy dynatron compensation. The grid current was reversed at all times in the 200-kW amplifier, the current, about -1 amps, becoming more negative with modulation. In the 50-kW regular two-tube set-up the grid current is negative 150 mA, and swings to positive values during modulation. This is shown on the oscillograms.

Dynatron grids may excite any circuit associated with them, and any combination of the elements of the grid-tank network may fix the frequency of a dynatron parasitic. Dynatron parasitics show nearly complete independence of the plate tank circuit, and most of the experiments with dynatron complications occurring with paralleled UV-862s were conducted with no plate tank at all. The plate voltage was fed directly to the plates through a 12-ohm resistor, inserted to prevent gas kicks from destroying the filaments.

An ultra-high-frequency dynatron parasitic was obtained by connecting the grid lead directly to the negative filament lead through a four-inch test clip lead, and applying half operating plate voltage. The circulating current was sufficient to explode the test clips. Pencil-like corona on Lecher wires indicated a frequency corresponding to about five meters.

The difficulties involving dynatron characteristics show that for higher than 200 kW in class B service, research toward a higher power triode free from this undesirable characteristic in necessary.

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So. Schenectady Development Station
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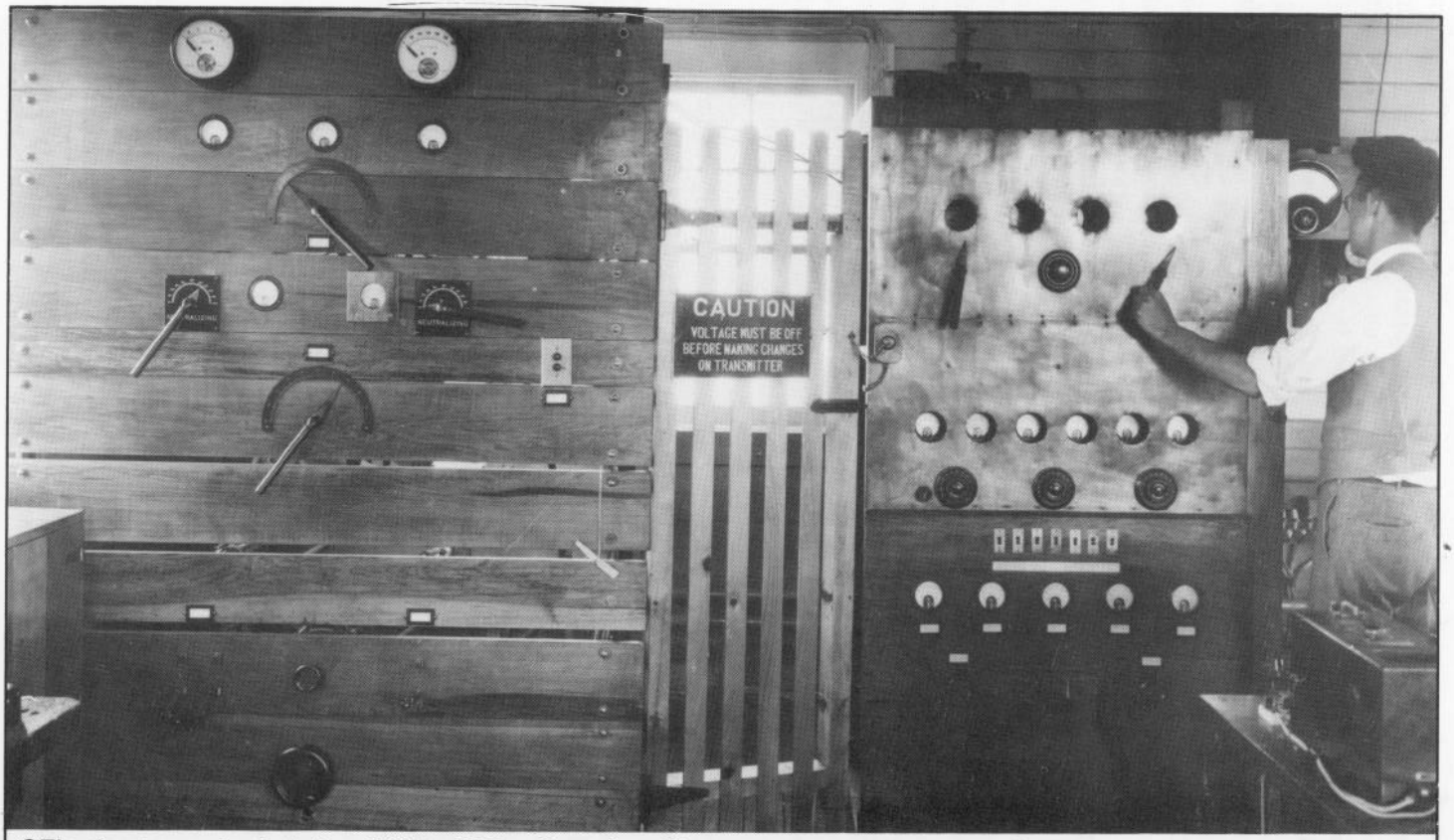


GE's short-wave test station 2XAD, 1928. Crystal oscillator and frequency multipliers at right; power amplifier at left. Wood outfits like this, innocent of shielding, were liberal sources of parasitic oscillation and other odd misbehavior.